(PUBLISHED QUARTERLY)

Journal of the Council for Scientific and Industrial Research.

Vol. 9. NOVEMBER, 1936. No. 4.

The Boron Status of South Australian Apples

*By C. S. Piper, M.Sc.,**

(*From the Waite Agricultural Research Institute, University of Adelaide.*)

Summary.

The boron contents of 48 samples of apples from the more important apple-growing districts of South Australia have been determined. The values obtained ranged from 12 to 30 parts of boron per million parts of dry matter, and, by comparison with New Zealand standards, it is concluded that boron deficiency is not likely to be found in the districts examined.

1. Introduction.

Although boron has been recognized as an essential element for some plants for a considerable time, interest has been stimulated recently owing to the fact that certain physiological diseases have been shown to be due to a deficiency of this element. Thus heart rot in sugar beet (1) and brown heart in swedes (2) are now recognized as boron deficiencies and are controlled by the use of fertilizers containing sodium borate. Askew (3) has also published results which suggest that a boron deficiency is the primary cause of "internal cork" of apples in New Zealand.

Since the boron content of any given variety of plant growing on a soil may be assumed to be an index of the boron status of that soil, it was decided to collect a large number of samples of apples from as wide an area as possible in South Australia and to determine their boron contents. Apples were selected for analysis because the New Zealand results already published by Askew would serve as a basis of comparison.

2. Analytical Methods Used.

The samples were collected at maturity and were held in cold storage until required for analysis. Each sample was restricted to the produce of a single tree, so that, if significant variations had been found between trees in any one orchard, it would have been possible to investigate them further. The method of analysis was essentially

* An officer of the Waite Agricultural Research Institute, University of Adelaide.

that of Dodd (4). The fresh apples were minced and 250 gm. aliquots were treated with caustic soda, in platinum dishes, dried in an oven, and ashed in an electric muffle at a low temperature. The charred residue was then extracted with water and re-ashed until carbon-free. The extract was evaporated and, together with the residue from the second ashing, dissolved in a small excess of dilute hydrochloric acid and filtered. After the addition of calcium chloride, the filtrate was made just alkaline to phenolphthalein, diluted to 100 ml., and filtered. 75 ml. was then titrated for boric acid. For this titration, N/25 lime water was used to avoid errors due to the presence of small amounts of carbon dioxide in caustic soda. Methyl red and phenolphthalein were used as indicators, and a concentrated solution of invert sugar, as recommended by Kolthoff (5), was used in place of mannitol. In every case, the amount of alkali necessary to change from the methyl red end-point to the phenolphthalein end-point was determined before the addition of the invert sugar. This was done in order to prove that no substances buffering over this range, other than boric acid, were present in significant amount.

Blank determinations were carried out at the same time, and using the same amounts of reagents as in the actual determinations. However, since a trace of phosphoric acid escapes precipitation unless the solution is made strongly alkaline to phenolphthalein (under which conditions some borate is also precipitated), 0.05 gm. of potassium hydrogen phosphate was added to the blank so that the conditions would be more comparable with the actual determinations on plant material. In every case the amount of phosphoric acid remaining in solution was determined by Zinzadze's colorimetric method (6) and this amount was found to be of the same order in both blank and actual determinations. This amount was equivalent to approximately one drop of the standard alkali used during the titration and was never sufficient to prevent very sharp end-points being obtained.

The amount of boron found by the above titration method was confirmed on a 2 ml. aliquot of the filtrate by Smith's colorimetric method (7). This method, which is extremely sensitive, depends on the intensity of the blue colour produced by boric acid in a solution of quinalizarin in 92 per cent. sulphuric acid.

Before commencing, and also during the course of the analytical work, experiments were made to test the recovery of known amounts of boric acid, added as sodium borate to apples prior to ashing. An average recovery of 93 per cent. was obtained by the above methods.

3. Experimental Results.

Forty-eight samples of apples were examined, and Table 1 shows the localities from which the samples were derived, the boron content (expressed as parts of elementary boron per million parts of both fresh and dry matter), together with an estimate of the prevalence of "bitter pit".

Samples 1–45, consisting of Jonathan and Cleopatra varieties, were collected from single trees in typical orchards throughout the various horticultural districts. In most cases two samples have been collected from trees of the same variety in each orchard, contrasting vigorous

Table 1.—The Boron Content of South Australian Apples.

Number.	Locality.	Variety. (a)	Average Diameter. mm.	Boron (B) p.p.m. In fresh material.	Boron (B) p.p.m. In dry matter.	Incidence of bitter pit. (b)
1	Millicent ..	C	65	1·7	12	33
2	,, ..	C	72	3·1	24	14 (c)
3	,, ..	J	57	3·3	19	0
4	,, ..	J	57	3·8	23	0
5	Joanna ..	C	68	2·9	20	40
6	,, ..	C	68	3·0	20	27
7	,, ..	J	59	3·1	21	0
8	,, ..	J	58	3·5	22	0
9	Coonawarra ..	C	60	3·2	20	6
10	,, ..	C	60	2·4	14	2
11	,, ..	J	57	3·4	19	0
12	Scott's Creek ..	J	62	4·0	28	0
13	,, ,, ..	J	62	2·7	19	2
14	Mylor	J	64	2·8	21	6
15	,, ...	J	64	2·6	18	0
16	Clarendon (1) ..	C	65	2·6	17	8
17	,, ..	C	63	2·6	17	0
18	Clarendon (2) ..	J	64	3·1	22	0
19	,, ..	J	61	2·8	21	0
20	Belair	C	65	4·2	27	0
21	,, ...	C	65	3·0	21	12
22	Balhannah ..	J	65	3·0	19	0
23	,, ..	J	64	4·1	29	0
24	Lenswood ..	J	74	3·1	20	0
25	,, ..	J	62	4·1	27	0
26	Cudlee Creek ..	C	65	2·6	21	3
27	,, ,, ..	C	65	1·7	13	4
28	,, ,, ..	J	61	2·5	18	0
29	,, ,, ..	J	60	2·5	18	0
30	Kersbrook ..	C	71	2·7	18	31
31	,, ..	C	71	3·1	19	5
32	,, ..	J	63	2·5	17	0
33	,, ..	J	66	3·5	22	0
34	Eden Valley ..	J	64	4·0	24	0
35	,, ,, ..	J	63	3·0	16	0
36	Williamstown ..	J	63	3·9	26	0
37	,, ..	J	62	5·4	30	0 (c)
38	Clare	C	67	2·5	18	15
39	,, ...	C	63	3·2	20	18
40	,, ...	J	57	4·3	26	3
41	,, ...	J	58	4·6	27	2
42	Angaston ..	C	66	2·7	22	19
43	,, ..	C	60	3·7	22	5
44	Wirrabara ..	J	61	3·9	24	0
45	,, ..	J	59	4·2	28	0
46	Paracombe ..	R.B.	64	3·1	18	55 (d)
47	Kersbrook ..	S.P.	54	3·9	26	83 (e)
48	,, ..	S.P.	64	3·4	25	7 (e)

(a) C = Cleopatra, J = Jonathan, R.B. = Rome Beauty, S.P. = Stone Pippin.

(b) This figure expresses the proportion of apples affected by bitter pit to the total number, and is set down as a percentage. In calculating this figure, slightly affected apples (1–4 lesions per apple) were rated at half the figure of those severely diseased. Owing to the small number (15–30 per sample), the figures given are intended to provide only a relative idea of bitter pit incidence in the different samples.

(*c*) Breakdown following water core also occurred in these apples.

(*d*) Apples affected with McAlpine confluent type bitter pit. Other apples in the sample not yet showing confluent pit were affected by water core, in some cases associated with core browning.

(*e*) Samples 47 and 48 were taken from the same tree; 47 includes apples severely affected with bitter pit and 48 apples practically free from the disease.

and weak trees, or trees considered to vary in susceptibility to bitter pit. The analyses, however, show no significant variations in the boron content of each pair of samples due to these factors. When the results are examined according to districts, it is seen that the boron content of the samples from the Northern District (Nos. 34–45) averages 23.6 parts per million parts of dry matter, whereas that of the samples from the South-Eastern District (Nos. 1–11) is lower at 19.5 p.p.m., and samples from the two districts comprising the Mt. Lofty Ranges (Nos. 12–33) occupy an intermediate position, averaging 20.5 p.p.m. In comparison with the New Zealand results given by Askew, these figures suggest that South Australian soils generally are well supplied with boron and that a deficiency of this element is not to be expected in the districts examined.

In addition to the above, three other samples (Nos. 46–48) have been collected. The Rome Beauty apples comprising sample No. 46 were all severely affected with "McAlpine's confluent bitter pit" while the two remaining samples represent Stone Pippin apples from a single tree. Most of the apples of sample No. 47 were severely affected with bitter pit, while those of No. 48 were almost entirely free from pit. The boron content of these three samples strongly suggests that neither of these types of pit is caused by a deficiency of boron as in the case of the New Zealand "internal cork".

4. Acknowledgments.

The author is indebted to Mr. A. G. Strickland and officers of the Horticultural Branch of the South Australian Department of Agriculture, who kindly undertook the collection of the various samples. Thanks are also due to Mr. D. B. Adam, of this Institute, who assisted with the examination of each sample and provided the estimate of bitter pit incidence.

5. References to Literature.

(1) F. Hanley and J. C. Mann. *J. Min. Agric.* **43**: 15-23, 1936.

(2) D. G. O'Brien and R. W. G. Dennis. *Scot. J. Agric.* **18**: 326-334, 1935.

(3) H. O. Askew. *N.Z. J. Sci. & Techn.* **17**: 388-391, 1935.

(4) A. S. Dodd. *Analyst* **52**: 459-466, 1927; and **54**: 282-285, 645-650, and 715-725, 1929.

(5) I. M. Kolthoff and N. H. Furman. Volumetric Analysis. Vol. II., p. 122. (J. Wiley and Sons, New York, 1929.)

(6) Ch. Zinzadze. *Z. Pflanz. Dung.* **16A**: 129-184, 1930.

(7) G. S. Smith. *Analyst* **60**: 735-739, 1935.

Downy Mildew (Blue Mould) of Tobacco: Prevention of its Development in Inoculated and Infected Seedlings by Benzol.

By A. V. Hill, M.Agr.Sc., and H. R. Angell, Ph.D.†*

Summary.

1. Downy mildew of tobacco was prevented by keeping seedlings in benzol vapour continuously from the time of inoculation for three to nine days, or intermittently for sixteen hours per day for three to six days. It was also prevented if the seedlings were kept in the vapour for eight or more days beginning at any time previous to sporulation.

2. Used after inoculation and before sporulation, benzol vapour kills most of the conidia and kills or inactivates the mycelium after the host is penetrated. If used after sporulation has begun, it almost prevents further production of conidia.

3. The experiments indicate that seedlings should not be unduly exposed to infection for a week or more before transplanting, as this may result in a few isolated transplants developing the disease.

I. Introduction.

In previous papers‡ it was reported that the occurrence of downy mildew of tobacco caused by *Peronospora tabacina* Adam was prevented if seedlings were exposed to benzol vapour§ for approximately sixteen hours each day. The eight-hour period each day during which the benzol was removed and the seedlings were uncovered for hardening-off was sufficiently long for germination of conidia, and perhaps penetration, to take place; yet no diseased seedlings were found in any seedbeds protected by the vapour from the recommended evaporating surface of benzol.

If conidia of the organism in drops of water on glass slides were exposed to benzol vapour in bell jars for sixteen hours, a few sometimes germinated after removal from the influence of the vapour. In experiments of the same type in seedbeds out-of-doors, it was found that less than 1 per cent., if any, germinated in concentrations of vapour that were effective in preventing the occurrence of the disease. The absence of the disease was all the more noteworthy because the inoculation was thorough and, as was shown by the effect on the control plants, conditions were very favorable to its development. According to the results of other experiments, if the use of benzol were delayed until soon after the organism began sporulation, few, if any, conidia were subsequently formed, and further spread of the disease was prevented.

---

* Assistant Pathologist, Division of Plant Industry, C.S.I.R.

† Senior Pathologist, Division of Plant Industry, C.S.I.R.

‡ Angell, H. R., Hill, A. V., and Allan, J. M.—Downy mildew (blue mould) of tobacco: Its control by benzol and toluol vapours in covered seedbeds. This *Journal*, 8: 203-213, 1935.

Angell, H. R., Allan, J. M., and Hill, A. V.—Downey mildew (blue mould) of tobacco: Its control by benzol and toluol vapours in covered seedbeds. II. This *Journal*, 9: 97-106, 1936.

§ In this paper, the term "benzol vapour" refers to the mixture of air with the vapour produced at ordinary temperatures from the given surface of benzol. The optimal concentration prevents the disease without injuring the seedlings.

In this paper, are reported the results of laboratory experiments concerning the length of time necessary for the prevention of the disease by the application of benzol (*a*) continuously from the time of inoculation, (*b*) continuously from some days after inoculation, or (*c*) intermittently, for sixteen-hour periods on successive days. They provide further evidence of the extraordinary efficacy of benzol vapour in preventing the disease.

2. Materials and Methods.

The experiments were begun in the spring of 1935 and were continued under the varying conditions of temperature and humidity that prevailed during the following summer and autumn. The majority were done under bell jars in the laboratory, a few in 18 x 18 x 18 in. glass cases in the greenhouse, and others in cold frames out-of-doors.

Healthy seedlings were grown in 6-in. pots in the greenhouse, the pots being covered with cellophane to prevent infection by conidia from nearby diseased seedlings. When the leaves of the seedlings were approximately one-quarter inch in diameter, the pots were transferred to the laboratory or placed in the glass cases or cold frames; the cellophane was removed, and the seedlings were inoculated by spraying with a suspension of conidia. In the laboratory experiments, benzol was added to a test tube of $\frac{5}{8}$ inch internal diameter until it was approximately $2\frac{1}{4}$ inches from the top, and the tube was then pushed into the soil to such a depth that the open end projected 3 inches above the level of the soil. Bell jars, 8 inches in diameter and 18 inches high, were then placed over the pots. The benzol was removed either after a certain number of days, or, in some experiments, for eight hours of each day. In other experiments it was not used until some days after the seedlings were inoculated. Subsequent to its removal the seedlings were allowed to remain under the bell jars either until some days after the disease was observed, or, failing its appearance, for two or more weeks. During the course of the experiments, examinations were made without removing the bell jars.

In the experiments in glass cases and cold frames, the evaporation surface of benzol was approximately 1-72 of the enclosed area. To minimize the risk of chance infection, the pots of seedlings were again covered with cellophane immediately after the period of exposure to benzol vapour. This course was necessary because of the prevalence of the disease in the immediate vicinity. In some instances, chance infection might have occurred during the time the seedlings were uncovered.

Seedlings similarly inoculated but left without benzol, and others exposed continuously to its action, were used as checks in every experiment. Each pot contained approximately 400 seedlings.

3. The Prevention of the Disease by Benzol.

(i) *Continuous Exposure.*

Pots of seedlings were inoculated and immediately exposed to the action of benzol vapour, as already described, for a varying number of days. From January to May, 1936, inclusive, 67 were used in eight

experiments under bell jars. In the early experiments, approximately four days' exposure to the vapour was sufficient to prevent the disease, but later, when the weather was cooler, a few diseased seedlings were observed in some pots that had been exposed for periods not exceeding eight days. Usually, the untreated control seedlings showed the disease five or six days after inoculation, and all died during the following week.

In two experiments in glass cases in the greenhouse, and in four in cold frames out-of-doors, more than 100 pots of seedlings were used. To prevent the development of the disease, it was necessary to expose the seedlings to the vapour for periods varying from three to eight days. The results were therefore comparable with those obtained under bell jars in the laboratory.

In general, continuous exposure for three days or less did not prevent infection of the majority of the seedlings, but few became diseased after longer treatment. The results showed that if seedlings were heavily inoculated with a suspension of conidia, nine consecutive days' exposure to the vapour was sometimes necessary to prevent the disease.

A summary of the results of three typical experiments is given in Table 1.

TABLE 1.—OCCURRENCE OF DOWNY MILDEW ON SEEDLINGS EXPOSED TO BENZOL VAPOUR IMMEDIATELY AFTER INOCULATION.

Date and Apparatus.	Number of pots of seedlings.	Days with Benzol.	Remarks.
16–4–36 ..	1	0	All diseased after 5 days and dead in 12 days
	2	3	Many diseased 6 days after removal of benzol
Bell jars ..	2	5	Few diseased 8 days after removal of benzol
	1	6	Less than one per cent. diseased 10–12 days after removal of benzol. No increase prior to secondary infection
	2	8	
24–9–35 ..	1	0	All subsequently diseased
	1	1	Many diseased seedlings
Glass cases in	1	2	Few diseased seedlings
the green-	1	3	No disease during 27 days after removal of benzol
house	1	14	No disease during 16 days after removal of benzol
17–4–36 ..	3	0	All subsequently diseased
	3	3	Many diseased seedlings
	3	5	Few diseased seedlings
Cold frame	3	7	Less than 1 per cent. diseased
out-of-doors	3	9	No diseased seedlings during 38 days after removal of benzol
	3	11	No diseased seedlings during 36 days after removal of benzol
	3	13	No diseased seedlings during 34 days after removal of benzol

(ii) *Intermittent Exposure.*

Pots of seedlings were inoculated in the morning, and placed under bell jars in the laboratory or in cold frames out-of-doors. Others were similarly treated in the afternoon, and benzol was then added to both series. On succeeding days the benzol was removed for eight hours.

In the four bell jar experiments with 24 pots, very few diseased seedlings were observed if benzol was used for 16 of the 24 hours of three consecutive days. Similar treatment for five days entirely prevented the disease. The results were the same, whether seedlings were inoculated eight hours previous to, or immediately before, exposure to the vapour. In two experiments in cold frames, 42 pots of inoculated seedlings were kept in benzol vapour for sixteen hours per day for as many as thirteen consecutive days. Many diseased seedlings were observed in pots that were exposed to the vapour for periods not exceeding three days. The number decreased as the number of days on which vapour was used was increased, until finally no disease was observed.

The results of two experiments are summarized in Table 2.

TABLE 2.—OCCURRENCE OF DOWNY MILDEW ON SEEDLINGS INTERMITTENTLY EXPOSED TO BENZOL VAPOUR.

Date, time of inoculation, and apparatus.	Time benzol added.	Number of pots of seedlings.	Number of 16 hour periods with benzol.	Remarks.
16–3–36 ..	4.45 p.m.	1	0	All diseased on sixth day
		1	3	Two diseased seedlings 6 days after removal of benzol
8.45 a.m... Bell jars	..	1	5	No disease during 21 days after removal of benzol
		1	7	No disease during 19 days after removal of benzol
18–4–36 ..	4.45 p.m.	3	0	All diseased on eighth day
		3	3	Many diseased seedlings
8.45 a.m...	..	3	5	Few diseased seedlings
Cold frame		3	7	Approximately 1 per cent. diseased seedlings
		3	9	Approximately 1 per cent. diseased seedlings
		3	11	Approximately 1 per cent. diseased seedlings in one pot only
		3	13	None diseased

(iii) *Exposure after Seedlings were Infected.*

At intervals of one to five days following inoculation, tubes of benzol were placed in pots of seedlings under bell jars. After a certain number of days, the benzol was removed, the seedlings remaining under the bell jars until the conclusion of the experiment.

In nine experiments in bell jars, two in glass cases in the greenhouse, and three in cold frames out-of-doors, a total of 136 pots of

seedlings was used. The usual time from inoculation to the appearance of the disease on the control seedlings was six days, but in a few instances it was as short as four, or as long as thirteen days. In order to make certain that benzol was applied before the disease appeared, it was usually added to the pots three days after inoculation. In every experiment, seedlings that were exposed continuously to benzol vapour for at least eight days remained healthy, provided it was applied before the disease appeared among the controls. On several occasions, benzol was added to pots on the day that conidiophores and conidia first appeared on some of the seedlings in them. In such cases the disease did not subsequently occur if the seedlings remained in the vapour for a sufficiently long time. In the majority of the experiments, the benzol was allowed to remain for more than eight days. After its removal, the seedlings were kept under the bell jars or covered with cellophane for two weeks or longer, but no disease developed.

The results of three experiments are summarized in Table 3.

TABLE 3.—THE EFFECT OF BENZOL VAPOUR ON THE DEVELOPMENT OF THE DISEASE IN INFECTED SEEDLINGS.

Date of inoculation, and apparatus.	Number of pots of seedlings.	Date benzol added.	Number of days exposed to benzol.	Remarks.
24–2–36 ..	1	0	0	All seedlings diseased 6 days after inoculation
Bell jars ..	3	26–2–36	14	No diseased seedlings during 14 days after removal of benzol
	2	27–2–36	13	No diseased seedlings during 14 days after removal of benzol
	2	28–2–36	12	No diseased seedlings during 14 days after removal of benzol
7–4–36	1	0	0	All seedlings diseased 6 days after inoculation
Bell jars	2	10–4–36	6	A few diseased seedlings in one pot
	2	10–4–36	8	No diseased seedlings during 21 days after removal of benzol
	1	10–4–36	10	No diseased seedlings during 21 days after removal of benzol
25–2–36	4	0	0	Seedlings diseased 6 days after inoculation
Cold frame	4	26–2–36	14	No diseased seedlings during 21 days after removal of benzol
	4	27–2–36	13	No diseased seedlings during 21 days after removal of benzol
	4	28–2–36	12	No diseased seedlings during 21 days after removal of benzol
	4	29–2–36	11	No diseased seedlings during 21 days after removal of benzol
	4	1–3–36	10	No diseased seedlings during 21 days after removal of benzol
	4	2–3–36	9	Some diseased when benzol was added ; all healthy during 3 weeks after removal of benzol

4. Discussion.

To prevent the disease under the conditions of the experiments reported in this paper, it was sometimes necessary for inoculated seedlings to be continuously exposed to the action of benzol vapour for more than eight days. However, only a few seedlings developed the disease after more than three days' exposure to the vapour. If the disease occurred, the appearance of conidia was usually delayed for a period not less than that during which the vapour was present. In different experiments, the variation in the time required to prevent the disease was due in part to weather and other factors that influenced the rate of evaporation of benzol.

In the commercial application of benzol for the protection of seedlings, it is necessary to remove the seedbed covers on all fine days to harden-off the seedlings for transplanting. Infection is likely to occur during the eight hours of each day when the covers and benzol are removed, but the disease does not develop. According to our experiments under bell jars, downy mildew does not occur if inoculated seedlings are placed in an atmosphere of benzol vapour for sixteen hour periods on six, or sometimes fewer, consecutive days. This is less time than is sometimes required if benzol is used continuously under similar conditions; therefore it seems that more effective control of the organism is obtained by the intermittent use of benzol. From the results of these and other experiments, it is apparent that removing the covers and the benzol from commercial seedbeds on fine days is not likely to result in disease among the seedlings.

Numerous experiments during the past seven years showed that the usual time elapsing between inoculation and appearance of the disease was seven days. Sometimes it was only four. In the fourteen experiments in the third series reported herein, it was usually five or six days. Under favorable conditions, conidia germinated in two hours, penetration followed, and growth of the mycelium proceeded until the conidiophores and conidia were formed. As, hitherto, control of this type of plant disease has been based on prevention of infection, it was expected that, if a seedling became infected, the use of benzol vapour would not inactivate the organism but that the disease would run its usual course. In these experiments, however, seedlings in which the mycelium was present were exposed to benzol vapour for eight days, or, in some cases, a shorter period, and they remained healthy after the benzol was removed. Since the disease did not appear within fourteen or more days after the removal of the seedlings from the influence of the vapour, it was concluded that the organism in the tissues was inactivated or killed. This appears to be the first time that the development of a pathogenic organism that has already established itself in the tissues of a growing plant has been shown to be stopped by the external application of a fungicide.

Under commercial conditions, comparatively few viable conidia fall in a seedbed. It is possible that seedlings, infected by such conidia shortly before transplanting, might develop the disease after removal from the influence of the vapour and so act as centres of infection in the field. In districts where downy mildew is likely to cause extensive damage in the field, it is therefore of great importance to prevent, as far as is practicable, contamination from diseased plants during the last week in the seedbed.

The Difference Between the Drying Rates at the Entering and Leaving Air Sides of a Kiln Charge of Timber.

*By W. L. Greenhill, M.E.**

The article that follows is the third of a series on kiln aerodynamics; the first and second articles appeared in the May and August issues, respectively.—Ed.

Summary.

A number of tests have been carried out in an experimental kiln to determine the change in air condition and drying rate from the entering to the leaving air side of a stack of timber 5 feet wide. Different sized separating strips and different quantities of circulating air have been used. The theoretical relation between the quantity of air circulated, the amount of moisture evaporated, and the change in air conditions has also been established, and the calculated air velocities required for certain conditions of drying have been compared with those determined experimentally.

1. Introduction.

In drying a stack of timber of commercial proportions, the heat necessary to evaporate the moisture must be carried to the timber by the circulating air which must also remove the moisture evaporated. It follows that the temperature and relative humidity of the circulating air must change as the air moves across the stack, and, furthermore, as the rate of drying is a function of the temperature and relative humidity, there must be a change in the rate of drying from the entering to the leaving air side of the stack. The timber at the leaving air side dries more slowly than that at the entering air side; the difference is known as the lag.

Some lag is inevitable, but it is dependent on the volume of air circulated as well as on the rate of drying and can be kept within reasonable limits by circulating sufficient air. In most commercial kilns of modern design, the disadvantages of lag are overcome to a large extent by providing for a periodic reversal of the air circulation. However, even under these circumstances it is undesirable to have a large lag. A large lag slows up the net drying rate because, when the circulation is reversed each time, the moisture content of the boards on the then entering air side of the stack is higher than would be the case if the lag were kept small. Then again, despite the alternate direction of air circulation, the rate of drying at the centre of the stack is, on account of the non-linear relation between lag and distance across stack, unavoidably slower than at the edges. This difference should be kept small by keeping the overall lag small.

In the design of a kiln for drying any particular class of stock, it is desirable to be able to calculate the quantity of air required for efficient and reasonably uniform drying. This may be done purely from theoretical considerations, but before results so obtained are of practical value they must be checked experimentally. A series of investigations carried out with this object in view is described in the present article.

---

* Officer in Charge, Section of Timber Physics, Division of Forest Products, C.S.I.R.

2. Material and Apparatus.

The timber used was blackwood (*Acacia melanoxylon*) supplied to the Division in flitches which were converted into sample boards 6 inches x 1 inch x 18 inches long. The sample boards were divided into seven kiln charges each of thirty boards which were not closely matched with each other, but each board in each charge was matched with a corresponding board in the other charges. The timber was green, with approximately 100 per cent. moisture, and free from degrade. Its basic density* averaged 34 lb. per cubic foot.

The tests were made in the experimental kiln designed for this class of work. The stacks of timber were 5 feet wide in the direction of air flow 16 inches high, and built with boards 18 inches long. Dummy boards were used in each stack, except for three rows near the centre which consisted of the green blackwood sample boards.

For the first four runs 1-inch separating strips were used; for run 5 the strips were $\frac{7}{8}$-inch thick, and for runs 6 and 7 they were $\frac{3}{4}$-inch.

The velocity of the air circulating between the test rows was measured in each run by the method described previously,† the anemometer being fitted with a small mirror in front of the dial to facilitate its being read through the small inspection door provided in the main kiln door. Corrections were made to the anemometer readings for the temperature of the air.

Dry and wet bulb temperature readings were taken at the entering air side of the sample boards, 18 inches long, 3 feet along, and at the leaving air side, respectively. Copper-eureka thermocouples were used for this purpose; they were located between the middle and bottom rows of sample boards. The water reservoirs for the wet bulbs were placed below the bottom row of sample boards so that any interference with the air circulation would not affect the drying rates. Wicks from the reservoirs were taken to the wet bulb thermocouples through small holes in the bottom row of sample boards. The pairs of thermocouples were offset one from the other across the length of the boards.

The thermocouple leads were taken outside the kiln and connected through suitable switches to a potentiometer which gave readings to within ± 0.01 millivolts or approximately $\pm \frac{1}{2}°$ F.

3. Procedure.

The middle of the three rows of sample boards in each run was used to measure the drying rate and each board from this row was weighed twice daily throughout the duration of the run.

The drying conditions in the kiln were maintained by means of an automatic recording control instrument set at approximately 140° F. dry bulb and 120° F. wet bulb, the bulbs being located at the entering air side of the stack.

Potentiometer readings were taken during the daytime only. They were made every hour during the first two or three days of each run when the air conditions were changing rapidly but less frequently

---

* Basic density $= \dfrac{\text{oven-dry weight}}{\text{soaked volume}}$

† See this *Journal* **9: 128, 1936.**

during the remainder of the run. At first, some difficulty was experienced in obtaining satisfactory readings on account of the fluctuating kiln conditions, these fluctuations (of the order of $\pm 3°$F.) occurring before the control instrument came into action. This difficulty was overcome by using hand valves in series with the automatically-operated valves on the steam supply to the kiln heating coils and humidifying pipe, and throttling the steam supply so that, when the automatic valves opened, about 20 minutes elapsed before the kiln conditions changed sufficiently for the valves to close again. During the period when the valves were open, potentiometer readings were taken of the eight thermocouple E.M.Fs. in order and then in reverse order. The average of the readings for each thermocouple was assumed to correspond to the average kiln condition at the point of location of the thermocouple.

A constant air velocity was maintained in each run but varied from run to run, this change being effected by altering the fan speed and/or baffling the fan intake.

Each run was continued until the moisture content was below 40 per cent. and, in run 5, until it was below 20 per cent. There seemed little to be gained by continuing the drying beyond about 40 per cent., as the drying rate had then become quite slow and the change in air conditions relatively small. At the conclusion of each run, check moisture content sections were cut from the centre row of sample boards.

4. Results and Discussion.

(a) Change in Drying Conditions from the Entering to the Leaving Air side of the Stack.

Three sets of curves are given in Fig. 1 showing the change in dry bulb temperature, wet bulb temperature, and relative humidity from the entering to the leaving air side of the stack. These curves are for runs 1 to 3 and are representative of the complete series of tests. They give the average figures obtained during drying from the initial moisture content of 100 per cent. to an average of 80 per cent. in each of the three runs. The changes across the stack during the remaining period of drying were similar in character but less in magnitude. Figures for the entering and leaving air conditions respectively are given for different stages of drying for each of the seven runs in Table 1.

It will be seen that the wet bulb temperature changes much less than the dry bulb temperature. For every 8 to 10° F. fall in the dry bulb temperature, the wet bulb temperature falls 1° F. While this approximate relation between the dry and wet bulb temperature changes may not be the same at all temperatures, it is probably fairly close over the range of temperatures used in kiln work.

(b) Change in Drying Rate from the Entering to the Leaving Air side of a Stack.

In the initial stages of the drying of a commercial stack of timber, the average drying rate decreases from the entering to the leaving air side due to the change in the air conditions, but it is quite possible that in any individual row of boards the variation across the stack may be far from regular. This was found to be the case in the present tests where, although the samples in each row were the same size and species, they were not closely matched in any way. On the other hand, the

TABLE 1.—ENTERING AND LEAVING AIR CONDITIONS AND A COMPARISION OF THE CALCULATED AND MEASURED AIR VELOCITIES.

Run.	Size of Separating strip.	Stage of Drying (stack average).	Average Drying Rate, Percentage moisture per hour.	Average Conditions of Entering Air. Measured Temperature. Dry Bulb °F.	Wet Bulb °F.	Measured Relative Humidity Percentage.	Average Conditions of Leaving Air. Measured Temperature. Dry Bulb °F.	Wet Bulb °F.	Relative Humidity Percentage. Measured.	Calculated.	Air Velocity feet per minute. Measured.	Calculated.
1	1″	From 100% to 80% m.c. ..	1·25	140	120	54	125	118½	81	86	146	151
		„ 80% „ 60% „ ..	0·63	140	120	54	131	119	69	71	„	127
		„ 60% „ 40% „ ..	0·35	140	120	54	135	119½	62	63	„	125
2	1″	„ 100% „ 80% „ ..	1·39	140	120	54	132	119	68	69	320	312
		„ 80% „ 60% „ ..	0·65	140	120	54	136	119½	60	61	„	290
		„ 60% „ 40% „ ..	0·35	140	120	54	137½	119½	57	58	„	252
3	1″	„ 100% „ 80% „ ..	1·54	140	120	54	134	119½	64	65	464	465
		„ 80% , 60% „ ..	0·66	140	120	54	137	119½	58	60	„	398
		„ 60% „ 40% „ ..	0·35	140	120	54	138	120	58	60	„	337
4	1″	„ 100% „ 80% „ ..	1·70	141	120	53	135	119	61	63	547	513
		„ 80% „ 60% „ ..	0·69	141	120	53	138	119½	56	58	„	412
		„ 60% „ 40% „ ..	0·35	141	120	53	139½	119½	54	56	„	423
5	⅞″	„ 100% „ 80% „ ..	1·54	136	113	48	126½	112	62	65	469	334
		„ 80% „ 60% „ ..	0·61	136	113	48	133	112½	51	53	„	408
		„ 60% „ 40% „ ..	0·35	136	113	48	134	112½	50	52	„	375
		„ 40% „ 20% „ ..	0·14	136	113	48	135	113	49	50	„	362
6	¾″	„ 100% „ 80% „ ..	1·13	140	120	54	124	118	83	91	171	170
		„ 80% „ 60% „ ..	0·62	140	120	54	132	119	67	69	„	185
		„ 60% „ 40% „ ..	0·35	140	120	54	135	119½	62	63	„	164
7	¾″	„ 100% „ 80% „ ..	1·67	140½	120	54	134	119	63	64	681	634
		„ 80% „ 60% „ ..	0·68	140½	120	54	138	120	58	58	„	654
		„ 60% „ 40% „ ..	0·35	140½	120	54	139	120	56	57	„	577

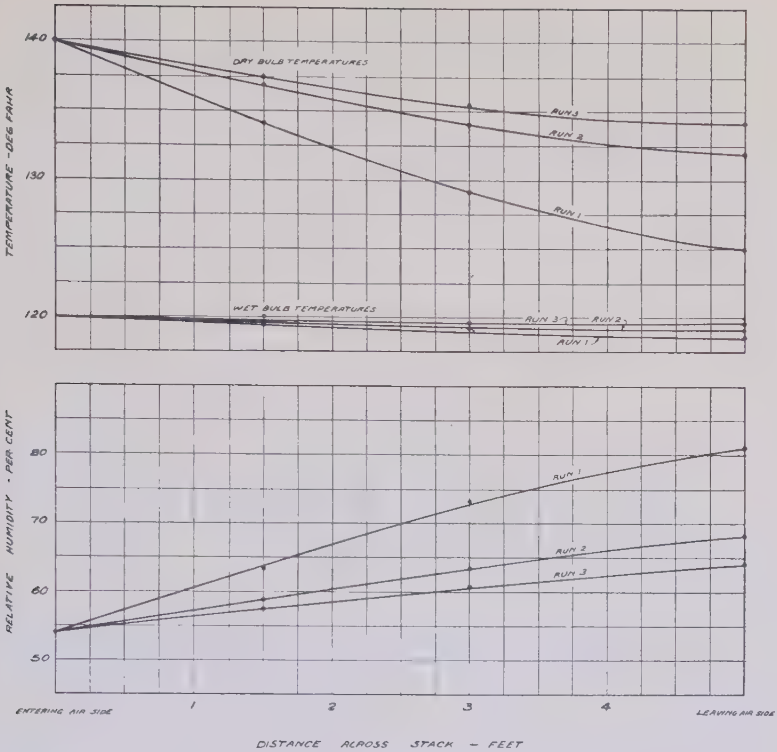


FIG. 1.—Average air conditions from entering air side to leaving air side of stack during drying from 100 per cent to 80 per cent. moisture content.

boards at corresponding positions in the stacks were matched in all runs, and it was found that the drying rates of the boards at the entering air side were practically the same in those runs in which the entering air conditions were the same. The air velocities varied widely, but in all cases were above the "critical velocity" described previously.* The rate of drying of the sample board on the leaving air side of each stack for any one stage of the drying varied according to the drying conditions at this point. Over the same moisture content range, the drying rate was found to be approximately proportional to the difference between the dry and wet bulb temperature. This relation made it possible, in combination with the results given in Fig. 1, to determine what the drying rates across the stack would be if all the boards were matched with those at the leaving air side. Curves obtained in this way are given in Fig. 2.

The comparison of drying rates from one side to the other of a stack of timber must, if the results are to be truly indicative of the changing air conditions, be made when the moisture content of all the boards is at least approximately the same. Immediately the moisture content across the stack becomes uneven, the boards with the higher moisture content at the leaving air side commence to dry more quickly than they

---

* See this *Journal* 9: 171, 1936.

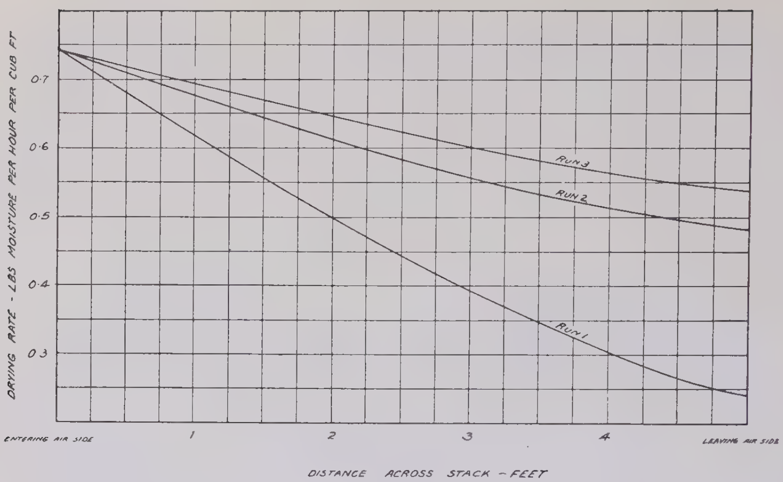


FIG. 2.—Average drying rates from entering air side to leaving air side of stack during drying from 100 per cent. to 80 per cent. moisture content (based on the assumption that all boards in stack similar to board on leaving air side.)

would under the same conditions if they were at the same moisture content as the boards at the entering air side. For this reason it generally happens that, toward the end of a kiln run, the drying rate at the leaving air side of a stack is greater than at the entering air side, although the drying conditions are less severe at the leaving air side. Eventually, all the material would reach the same moisture content, namely, the equilibrium moisture content corresponding to the conditions of the air, but it is generally impracticable to leave timber in a kiln for a sufficiently long period to accomplish this.

(c) *Quantity of Air required.*

The air velocities measured by the anemometer in each run are given in Table 1. The calculated air velocity required is also given. Actually, the quantity of air and not the air velocity is the governing factor, but, in measuring the quantity, the usual method is to measure the average velocity and then multiply by the area of the opening and air velocities are more commonly spoken of than air quantities.

The method of calculating the quantity of air required to establish a certain drying rate is given in an appendix. Besides the entering air temperature and relative humidity, it is necessary to know either the leaving air temperature or relative humidity. The leaving air temperature has been used in the present calculations, and the leaving air relative humidity has been calculated. This is also given in Table 1.

It will be seen that the calculated velocity is, in practically all cases, somewhat less than that measured. This is probably due to the fact that the calculated figure gives the *minimum* velocity required, whereas actually it appears that some of the air passes through the stack without accomplishing the desired result. This conclusion is further substantiated by the fact that the actual relative humidity of the leaving air

was, in nearly all cases, slightly less than that calculated. For practical purposes, the calculated air velocity should be increased by about 20 per cent.

Information concerning the kiln conditions to be used for drying various timbers and the corresponding drying rates has been obtained at this laboratory for many of the important Australian timbers, and this information can be used in calculating the air velocities required for drying these timbers, allowing a reasonable lag from the entering to the leaving air side of a stack. A 20 per cent. lag in the initial stages of drying is considered a reasonable amount for an efficient kiln.

Appendix.

The Theoretical Calculation of the Quantity of Air Required to be Circulated through a Stack of Timber.

In the drying of a stack of timber of commercial proportions, the heat necessary for the evaporation of the moisture must be conveyed to the timber by means of the air passing through the stack. It follows that, if the temperature and humidity of the air entering the stack are specified, then the temperature or the humidity of the air leaving the stack is predetermined as well as the amount of moisture which may be evaporated.

If the humidity of the leaving air is to be assumed in order to calculate its temperature, care must be taken that the assumed figure is within the limits imposed by the quantity of vapour per lb. of dry air entering the stack.

Since volumes change with changes in pressures and temperatures, 1 lb. of dry air with its accompanying moisture will be considered in the present calculations. The independent pressures of the air and of the vapour will vary according to the relative humidity and the temperature, but it is assumed that the total pressure always remains at atmospheric.

The heat required to evaporate 1 lb. of moisture will be the latent heat of vaporization, plus the amount necessary to raise the temperature of the water from some initial temperature at which it is placed in the kiln, plus the heat necessary to raise the temperature of the timber containing 1 lb. of moisture. There is also to be considered the heat of adsorption which should be included when drying takes place below the fibre saturation point. In practice, the stack of timber is usually heated before appreciable drying begins, so that, in considerations involving the quantity of air to be circulated, it can be assumed that the timber and the moisture are already heated to the temperature at which evaporation occurs. Furthermore, as the heat of adsorption is very small, this quantity can be neglected. Such a procedure is further justified by the fact that the faster drying rates for which the quantity of air must be provided in most cases occur when the timber is above fibre saturation point.

Let t_1 and t_2 be the entering and leaving air temperatures respectively, and h_1 and h_2 the corresponding relative humidities.

Let d_1 and d_2 be the lbs. of water per lb. of dry air entering and leaving respectively.

Let r be the specific heat of air at constant pressure, and s that of superheated vapour.

Let L be the heat required to vaporize 1 lb. of moisture from and at t_2.

The amount of heat given up by a lb. of air in passing through a stack is:

$$(r + d_1 \,.\, s)\ (t_1 - t_2)$$

The amount of water evaporated is (d_2—d_1), and the heat required is L (d_2—d_1). These two equations are equal, hence:

$$(r + d_1 \,.\, s)\ (t_1 - t_2 = L\,(d_2 - d_1)$$

or

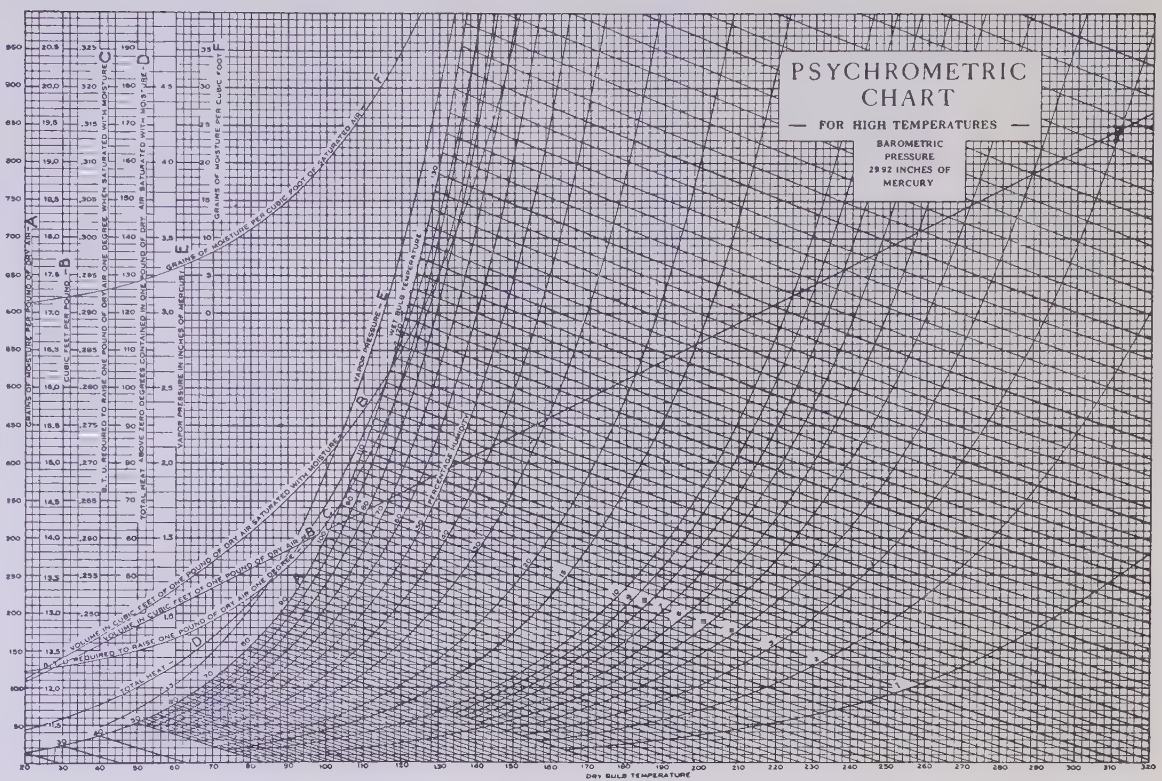
$$\frac{L}{r + d_1 \,.\, s} = \frac{t_1 - t_2}{d_2 - d_1} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

It can be assumed that the entering air temperature (t_1) and relative humidity (h_1) are known, so that d_1 can be determined from a psychrometric chart such as is shown in Fig. 3. It is important to remember that the amount of vapour contained in a lb. of air alone when it is saturated cannot simply be multiplied by the relative humidity to obtain the amount of vapour contained in the lb. of air alone at that relative humidity. When the air is saturated, the pressure of the air alone will have been reduced by an amount corresponding to the increase in vapour pressure, the sum of the two being one atmosphere, so that for a lb. of air a much greater space is required and an equivalently greater weight of vapour will be occupying this larger space.

It is required to find d_2—d_1, the amount of water evaporated per lb. of dry air. Obviously, either the temperature or the relative humidity of the leaving air must first be assumed. If we know t_2, the calculation of d_2 is simple, as all other factors are known or can be determined from tables. The specific heat of air (r) is 0.2375, and that of superheated vapour (s) is 0.475. L varies with t_2 and can be determined from steam tables.

The problem is not quite so simple when the relative humidity of the leaving air is assumed instead of the temperature. In this case, L is known approximately only as it depends on t_2. The relation between t_2 and d_2 is complex and cannot be expressed by any simple equation; it is generally shown by means of curves (see Fig. 3). For short intervals, the relation may be taken as a straight line, and the equation obtained from two points close together may be used for the local calculation. The straight line equation may then be introduced into (1). L may as a first approximation be taken as at t_1 and the equation solved for t_2. The more nearly exact value of L at t_2 may then be substituted and the equation again solved for t_2. From this value of t_2, the straight line equation derived from the curve may be used to find d_2.

The quantity of dry air by weight to evaporate 1 lb. of moisture is $\frac{1}{d_2 - d_1}$ lbs. The volume occupied by this weight of dry air can be obtained from Fig. 3, thus:—Determine the dew-point, i.e., the temperature (t_{dp}) to which the air must be cooled before it becomes



(by kind permission of Carrier Australasia Ltd.)

FIG. 3.—Psychrometric Chart.

saturated. From the same chart the volume occupied by 1 lb. of air when saturated at this temperature can be read off. Let this be V_{dp}. Then:

$$V_{dp} \cdot \frac{1}{d_2 - d_1}$$

gives the cubic feet of air required at t_{dp} to evaporate 1 lb. of moisture. But the volume is required at t_1, the temperature of the air entering the stack. The volume will vary directly as the absolute temperature, so that the volume at t_1 is:

$$V_1 = V_{dp} \cdot \frac{459.4 + t_1}{459.4 + t_{dp}} \cdot \frac{1}{d_2 - d_1} \qquad \ldots \qquad \ldots \quad (2)$$

This gives the volume of air, with its moisture, required to evaporate 1 lb. of moisture.

The quantity of moisture to be evaporated in unit time must next be determined. Let m be the moisture content per cent. (based on oven-dry weight of wood) by which the timber is dried in unit time. Let W_{od} be the oven-dry weight of 1 cubic foot of green wood Then $\frac{m \,.\, W_{od}}{100}$ is the weight of moisture to be evaporated per unit time from 1 cubic foot of wood.

Let the timber in the stack be t units thick, the width of the stack w, and the thickness of the separating strips s. Let the number of layers or openings be n. Consider a piece of the stack of unit dimensions lengthwise. The volume of timber $= t \,.\, w \,.\, n$.

Weight of moisture to be removed per unit time $= t.w.m.n.W_{od} \cdot \frac{1}{100}$

Volume of air required $= t \,.\, w \,.\, m \,.\, V_1 \,.\, n \,.\, W_{od} \cdot \frac{1}{100} \qquad \ldots \qquad \ldots \quad (3)$

$$\text{Velocity of air} = \frac{\text{Volume}}{\text{opening area}} = \frac{t \,.\, w \,.\, m \,.\, V_1 \,.\, n \,.\, W_{od}}{s \,.\, n \,.\, 100}$$

$$= \frac{t \,.\, w \,.\, m \,.\, V_1 \,.\, W_{od}}{s \,.\, 100} \qquad \ldots \qquad \ldots \quad (4)$$

Strength Tests Perpendicular to the Grain of Timber at Various Temperatures and Moisture Contents.

*By W. L. Greenhill. M.E.**

The investigations described herein were carried out at the Forest Products Laboratory, Madison, U.S.A., in 1931. The opinion was recently expressed that the results of these investigations are of sufficient fundamental importance to warrant their being published, and the present article has been prepared for this purpose.—Ed.

Summary.

Equipment has been obtained and a procedure established to enable tests of the tensile strength perpendicular to the grain to be carried out on a number of specimens of beech at various temperatures and moisture contents. Results are given of the maximum load, the load at elastic limit, the modulus of elasticity, and the unit deformation at maximum load. The value of such information in connection with fundamental considerations of seasoning problems is pointed out, and the need for extending the investigations to include other strength properties and to embrace other species is emphasized.

1. Introduction.

A complete understanding of many timber seasoning problems depends on a knowledge of the strength properties in tension and compression perpendicular to the grain as functions of temperature and moisture content. Most seasoning losses are produced by drying stresses; checking, honeycombing, and casehardening are all directly associated with a self-applied load produced by varying tendencies of the wood to shrink because of a necessary moisture gradient. If wood is stressed beyond the elastic limit, but less than the maximum, it will become "set"; if the load exceeds the maximum, the wood will fail.

Little information is available relating to the strength of wood in tension and compression across the grain as functions of moisture content and temperature. However, the determination of such information is essential if the science of seasoning timber is to be based on the fundamentals of drying rather than on the present methods of trial and error.

The investigations described in the present article may be considered as a beginning in this field of study. These investigations relate to the strength, in tension perpendicular, of beech; to be complete, they should be extended to include other species, compression tests, and also the effects of tension and compression dead loads. Although incomplete, it is thought that the results of the present work will be of value in the formulation of drying schedules for the species concerned, and the experience gained in these tests may serve to point the way to an improved technique in future studies of a similar nature.

2. Preliminary Tests.

The main tests were to be carried out at various controlled temperatures with the test pieces enclosed in a box, and it was obvious that difficulties would be met in attempting to measure the deformation

* Senior Timber Physics Officer, Division of Forest Products.

over some specified gauge length by attaching an extensometer to the test piece itself. For this reason, provision was made for measuring, outside the box, the overall deformation. At the same time, however, it was realized that, owing to mashing of the test piece lugs (see Fig. 1) and deformation of the grips, the deformation per unit length of a specimen, obtained by dividing the overall movement by the distance between the grips, would probably be in excess of the true value. Consequently, a number of preliminary tests were carried out under normal room conditions measuring both the overall movement and that recorded by an extensometer over a certain gauge length.

For these preliminary tests, a Riehle Universal 10,000 pound testing machine was used. This was fitted with a one-tenth sliding weight giving readings of one-tenth the normal value. The machine was geared down to a speed of 0.0288 inches per minute. The Moore extensometer used was attached to the test piece over a gauge length of 2 inches, by means of screwed points, and readings were taken by means of a dial gauge so placed as to give twice the actual value of the deformation. The overall elongation was measured by means of a dial gauge mounted between the moving head and the frame of the machine. Both gauges were read to the nearest thousandth of an inch.

The material used was similar to, and representative of, that used for the main tests; in all, 35 green test pieces were used.

In these preliminary tests, it was arranged for one person to operate the machine and one to read the gauges. Readings were taken every 10 lb. increase in load. After rupture, the position and angle of the fracture were noted, and a carbon impression taken of the growth rings to enable the average angle of the rings to be measured over both the 2″ gauge length and over the total 6″ between the grips. Stress strain curves were drawn and the strength properties computed.

1. The gauge modulus of elasticity = overall modulus of elasticity × 1.58.
2. Elastic limit = the overall measured elastic limit ÷ 1.20.
3. Unit deformation at ultimate strength = overall measured unit deformation at ultimate strength ÷ 1.24.

The fractures invariably occurred at right angles to the rings, that is, along the direction of the rays, and between 70° and 90° to the axis of the test piece. There was no evident relationship between the angle of the rings and the various strength properties, and as both these and the test pieces for the main tests were fully back-sawn, no attempt was made to adjust the above correction factors for different angles of rings.

The adoption of these correction factors for the main tests assumed that they applied similarly to the other conditions of moisture content and temperature of the test pieces. While this assumption was not strictly justified, it seemed better to make such a correction than to take the overall figures directly.

3. Main Tests.

(i) *Material and Its Preparation.*

The species used for the tests was North American beech (*Fagus grandifolia*). The material had been supplied to the U.S. Forest Products Laboratory primarily for the investigation of strength properties and the determination of a suitable kiln drying schedule.

For the tension perpendicular tests, about 50 back-sawn boards 9″ x 1″ x 48″ long were used. Forty-four of these consisted of sapwood and 6 of truewood (heartwood). The boards were sawn from approximately 20 logs.

Immediately they were cut, about 12″ was docked from each board and these short pieces were kept green in damp sawdust. The remaining 36″ lengths were then kiln dried as part of a kiln charge consisting in all of about 2,000 super. feet of beech and maple. The kiln was of the internal fan type and the schedule followed was very mild. At approximately 20 per cent. moisture content, the boards were removed from the kiln and a further 12″ docked from each. This procedure was repeated at 14 per cent. moisture content. The final 12″ lengths were dried to 7 per cent. The 20 per cent. and 14 per cent. moisture content samples were kept in closed boxes over suitable salt solutions to maintain them at their respective moisture contents. The 7 per cent. moisture content samples were kept at room conditions which approximated to an equilibrium moisture content condition of this value, the rooms being centrally heated.

These 12″ samples were subsequently cut up into test pieces, the size and shape of which are shown in Fig. 1. An attempt was made to obtain four of these test pieces from each 12″ sample, but, owing to defects in some of the material, this was not always possible, and in a few instances the whole sample had to be discarded.

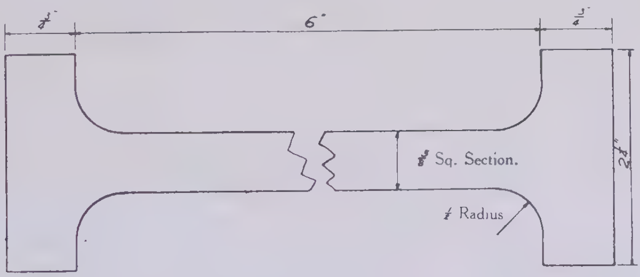


Fig. 1. Details of Test Piece used.

The test pieces were prepared from the 12″ samples by first surfacing and thicknessing accurately to $7\frac{1}{2}''$ x $\frac{5}{8}''$, and then cutting into $2\frac{1}{4}''$ lengths. These were roughed into shape on a bandsaw and then placed, one at a time, in a special form and finished off accurately on a shaping machine.

After the test pieces were prepared, they were maintained at their respective moisture contents until they were to be tested.

(ii) *Apparatus.*

The apparatus with which the strength tests were made is shown in Plate 1, Fig. 1. It consists of a mild steel lever and framework by which the stress was placed on the specimen through suitable grips. The framework and part of the lever were enclosed in a carefully constructed box provided with a door, window, small covered handhole for manipulating the specimens without opening the main door, and a flexible sleeve where the lever passed through the side. The

box was more or less air tight and was lined with a heat insulating fibre board. Shelves were placed at the back of the box to accommodate a number of test pieces.

A steam coil was accommodated in the bottom of the box. Any desired temperature was maintained in the box by an automatic temperature-controller fitted on the steam supply line. The humidity in the box was determined by a concentrated salt solution kept in a tray which rested on the steam coils. The salts used were selected on each occasion, so that the moisture content of the specimens being tested remained unchanged.

The load on the sample was applied at a uniform rate by running water from a constant head into a vessel at the end of the lever arm. A counterweight was arranged to take care of the weight of the lever and vessel. The length of the lever was such that the load on the sample was 10 times the weight applied. The grips for the specimen were designed to pivot in each direction to insure an even pull.

The deflections of the lever were measured by means of a dial gauge outside the box halfway between the fulcrum and the point of application of the water load. As the load on the test piece was at one tenth this distance, it follows that the deflection read was five times that of the test piece. Actually, it was found that the lever arm and framework deflected to some extent. This was tested from time to time by placing rigid metal strips between the points of attachment of the grips and measuring the deflection at the gauge when the weight was applied. This was found to be an elastic deflection and to remain constant; all gauge readings were corrected accordingly.

(iii) *General Procedure.*

The tests were carried out at temperatures of 80°, 120°, 160°, and 180°F., and with material of each of the moisture contents 7 per cent., 14 per cent., 20 per cent., and green. There was to have been one specimen for testing at each temperature and moisture content from each of the 50 boards originally selected but, as explained previously, this number was reduced somewhat due to faulty material.

In the testing procedure adopted, the specimens for each particular series were placed in an auxiliary oven at 4 p.m. one day and maintained at the desired temperature and moisture content until the same time the next day, when they were transferred to the testing box and held under similar conditions until the third day when they were tested. The actual testing lasted about 5 hours, so that it was possible to work every day and at the same time subject the specimens to the conditions at which they were to be tested for at least 40 hours prior to the test. Work by Pillow(2) has indicated that after this period the temperature effect has practically reached its maximum.

The saturated salt solutions used to give the various conditions of equilibrium moisture content were chosen from the lists given by Spencer(4) in the International Critical Tables. Details of these are shown in Table 1.

Actually, the humidity conditions obtained varied considerably from those desired; it is thought that the addition of fans to the conditioning and testing boxes would have given more satisfactory results.

TABLE 1.

Moisture Content Per Cent.	Temperature °F.	Relative Humidity. required.	Saturated salt solution used.
Green	80	100	Water alone
	120	100	,, ,,
	160	100	,, ,,
	180	100	,, ,,
20	80	90	K_2SO_4
	120	92	,,
	160	94	Water alone
	180	96	,, ,,
14	80	74	NaCl
	120	79	,,
	160	85	KCl
	180	88	K_2SO_4
7	80	..	Room conditions
	120	43	$Co\,Cl_2.\ 6\ H_2O$
	160	53	$NaNO_3$
	180	58	KNO_3

As the test pieces were all in the test box at the commencement of each series of tests, it was possible, by operating through the small hand hole, to place them in the grips without disturbing the conditions in the box to any appreciable extent. An initial load was placed on the test pieces. In different series of tests, this varied from 10 to 100 pounds according to the elastic strength of the specimens. The vessel for the water and the lever were counterbalanced prior to the run, and the Ames gauge set at zero when the initial load had been added. The constant head of water and the diameter of the discharging pipe were such as to give a rate of loading of about 1 pound per second. The head of water was maintained constant by an overflowing reservoir.

The water was turned on and a stop-watch started simultaneously. Gauge readings were taken every ten seconds. When the specimens broke, the stop-watch and water were both stopped immediately, the water weighed, and the watch read. As the rate of flow was constant, it was then possible to check this rate for each test and to estimate the load at each gauge reading. Immediately after the test, the cross sectional dimensions of the test piece were measured to the nearest thousandth of an inch and the smaller part of the broken specimen was taken for a moisture content determination.

A typical set of fractures is shown in Plate 2, Fig. 1. A few of the fractures occurred in the enlarged sections at the necks of the specimens. In these cases the results were discarded.

The stress strain curve was drawn for each test and the strength values calculated in the usual manner, the respective empirical corrections found in the preliminary tests being applied.

(iv) *Results.*

The results have been summarized in Table 2 in which the average values for the sapwood pieces are shown. The standard deviation has been calculated from the curve given by Shewhart(3). The values for the truewood test pieces are not given, but, as far as could be judged

TABLE 2.—STRENGTH IN TENSION PERPENDICULAR OF BEECH AT VARIOUS TEMPERATURES AND MOISTURE CONTENTS.

Nominal Conditions.		Number of Test Pieces.	Actual Temperature °F.		Actual moisture content (per cent.)		Maximum Load (lb. per sq. in.)		Load at Elastic Limit (lb. per sq. in.)		Modulus of Elasticity (lb. per sq. in.)		Unit deformation at maximum load (inches.)	
Temperature °F.	Moisture Content. (Per cent.)		Average.	Std. Dev.	Average.	Std. Dev.	Average.	Std. Dev.	Average.	Std. Dev.	Average.	Std. Dev.	Average.	Std. Dev.
80	7	33	75	2	6·3	0·3	1,535	250	1,071	128	179,000	13,950	·0121	·0019
	14	38	84·5	2	20·2	0·8	1,037	91	406	85	112,400	14,400	·0184	·0029
	20	32	74	1	24·0	2·0	1,031	94	491	107	98,700	12,000	·0184	·0041
	Green	37	75	3	103	8·0	902	91	451	59	84,300	10,700	·0199	·0032
120	7	34	123	2	7·6	0·2	1,437	197	774	104	126,200	17,200	·0180	·0032
	14	37	123	2	17·9	0·6	963	142	418	96	83,900	13,000	·0224	·0053
	20	36	123	2	24·1	0·8	846	99	347	85	61,150	10,300	·0281	·0056
	Green	38	124	2	102	8·0	724	75	363	41	60,600	8,300	·0246	·0129
160	7	26	162	1	9·5	0·5	1,178	167	653	88	95,100	14,900	·0212	·0047
	14	16	159	3	15·0	0·5	939	175	588	132	94,100	18,700	·0150	·0031
	20	19	162	2	25·8	0·7	538	68	243	48	40,300	6,300	·0199	·0043
	Green	35	151	3	102	8·0	527	64	250	32	41,190	5,500	·0228	·0031
180	7	16	181	1	4·0	0·4	1,402	208	744	78	149,300	21,100	·0139	·0024
	14	7	179	1	9·2	0·6	997	157	415	37	76,600	9,000	·0249	·0064
	20	11	179	1	15·1	0·8	675	111	280	95	65,200	14,600	·0207	·0082
	Green	27	180	2	97·0	9·0	410	45	179	12	32,460	4,500	·0212	·0038

from the small number of tests, they were not appreciably different from the sapwood specimens as regards these particular strength values. The truewood test pieces have not been considered in the subsequent curves.

In view of the fact that the moisture contents varied so much from the nominal values and from series to series, although there was little variation within any one series, while the temperatures were comparatively constant, preliminary curves were drawn for the maximum load, load at elastic limit, modulus of elasticity, and unit deformation at maximum load, respectively, against moisture content for each temperature. For these curves the points were plotted from the data and the curves drawn to smooth out any irregularities. Slight adjustments were made for the values of the 14 per cent. moisture content test pieces supposed to be at 80°F. and for the green test pieces supposed to be at 160°F.

From these preliminary curves, the values of the strength properties at 5, 10, 15, 20, and 25 per cent. moisture content and at the green condition have been read off and plotted against temperature in Figs. 2, 3, 4, and 5. From these sets of curves it is possible to obtain fairly closely these particular strength values for beech within the range of conditions covered.

4. Discussion.

Except in the case of the green specimens, the tests at the two higher temperatures were not entirely satisfactory. However, by tying the curves into the group and carefully weighting irregular points, what is thought to be a fairly accurate series of results has been obtained.

It is realized that the method of correcting the overall deformation in all cases by the factor obtained in the preliminary test leaves much to be desired, but the possibility of attaching a gauge to each specimen at the higher temperatures seems out of the question.

The following general conclusions as to the tensile strength of beech perpendicular to the grain have been reached:—

1. The maximum strength is affected most by high temperatures at moisture contents above 10 per cent. Even at low temperatures, such as might be met in ordinary summer, however, the strength decreases with an increase of temperature; with moisture contents above 20 per cent., the rate of decrease becomes much greater above 100°F., falling off again above 160°F.; at the lower moisture contents, the strength falls off at a gradually increasing rate up to 180°F.

2. The load at elastic limit decreases gradually with increasing temperature up to about 100°, after which the rate of decrease becomes much greater.

3. The modulus of elasticity is affected in a similar way by high temperatures to the elastic limit.

4. The unit deformation at maximum load reaches a maximum in the neighbourhood of 120° at all moisture contents.

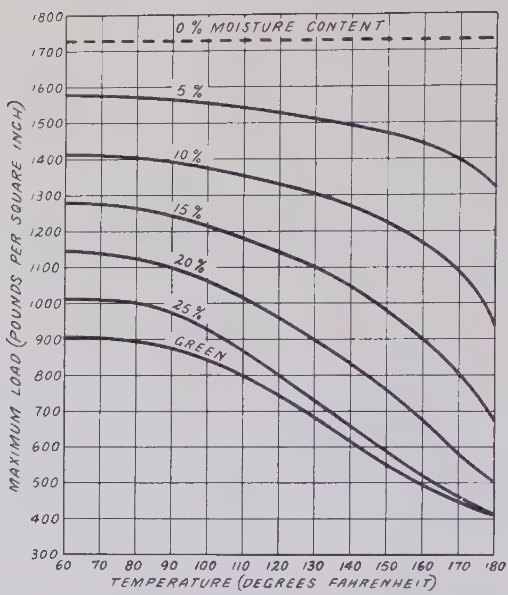


FIG. 2.—Relation between maximum load and temperature at different moisture contents.

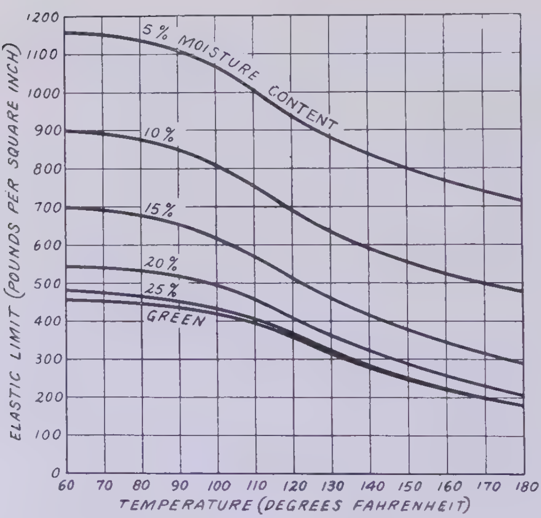


FIG. 3.—Relation between load at elastic limit and temperature at different moisture content.

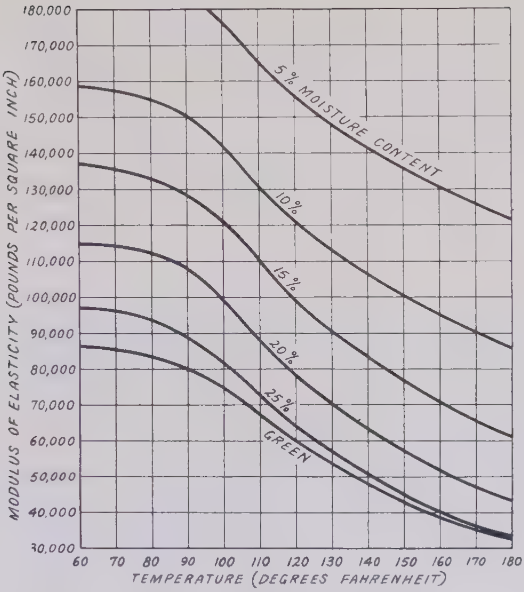


FIG. 4.—Relation between modulus of elasticity and temperature at different moisture contents.

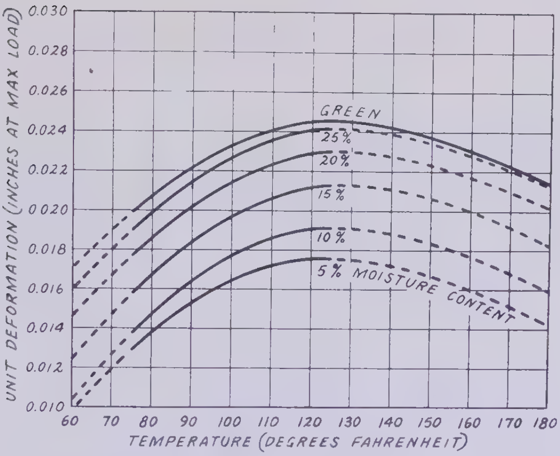


FIG. 5.—Relation between unit deformation at maximum load and temperature at different moisture contents.

The convergence of the maximum load curves to zero moisture content (Fig. 2) is of interest. Obviously, the indication that the maximum strength is independent of temperature at zero moisture content has definite temperature limits.

That the unit deformation at maximum load reaches a maximum at about 120°F. indicates that the use of temperatures in this neighbourhood would be least likely to cause checking in the kiln drying of this species. However, the variation of the unit deformation over the range covered is not large.

The unit deformation at the elastic limit can be obtained readily from the load at elastic limit and the modulus of elasticity. The actual value of this is about 0.005 to 0.006 in all cases. Such a value enables the conditions which will produce "set" in the timber during drying to be calculated.

It is interesting to note that the results indicate a lower fibre saturation point with increase in temperature. Evidence for this can be seen in the convergence of the 25 per cent. moisture content and green curves in Figs. 2, 3, and 4. This behaviour is in agreement with the moisture equilibrium curves given by Hawley(1).

The relation of specific gravity to both the maximum load and the modulus of elasticity was investigated using a number of representative test pieces. While the correlation was not particularly obvious, there was a definite tendency for the denser test pieces to be both stronger and stiffer. The variation in density might, therefore, be expected to account to some extent for the range of strength values in each series of tests.

A number of the fractures were examined under the microscope. The failures were always radial and the fractures appeared to occur mainly by the separation of the ray cells, but, of course, it would be impossible for them to occur entirely in this manner since the rays of beech are not continuous over as large an area as the cross section of the test pieces. Consequently, the failure must be partially through fibres and vessels.

Two of the most important factors which affect specific gravity are :—(i) the proportion of vessels or pores to fibres, and (ii) the thickness of the cell walls, together with size of cell cavities. Consequently, since the failure cannot be entirely between rays and adjacent fibres or within the rays, a specimen of low density, that is, with more vessels, would offer less resistance to a tension perpendicular force than a heavy specimen with fewer vessels.

Probably because of their relatively thin walls and large diameters, vessels are torn through more or less diametrically, while fibres with thicker walls and smaller diameters are separated one from another with the failure within the walls of fibres on one side of the failure.

Since the failure of the fibres seemed to be a separation within the fibre wall rather than a tearing progressing diametrically through complete fibre walls and fibre lumens, it would seem that the character of the wall rather than the amount would be the more important factor in connexion with the failure of the fibre walls. The failure progressed from one fibre to another across the middle lamella of radially adjacent cells. When within the cell wall, it was always closer to the middle lamella than to the lumen (see Plate 2, Fig. 2).

5. Suggested Modifications for Future Tests.

Throughout the tests the apparatus proved satisfactory, although it had not been designed for the higher loads encountered. Elastic deformation of the lever and framework were very apparent, however, and although these were allowed for in calculations of deflections, a more rigid construction would be preferable for loads exceeding 350 pounds.

The particular method of loading employed, while quite sound, was somewhat clumsy, and provision might be made to have an electric motor to apply the load, at the same time retaining the principle of a constant rate of loading rather than a constant rate of deflection. A motor rotating a screw which moves a weight along a lever arm is a suggested method.

It would be advantageous to have a vertical rod from the lower test piece grip passing out through the bottom of the box and thus have the complete lever system outside. A stuffing box for the vertical rod could be made to seal the box effectively much more simply than the sleeve used on the lever.

It is also desirable to make provision for using the apparatus for compression tests as well as for static loading tests of both compression and tension.

The box could with advantage be made somewhat larger and with better provision for accommodating samples not actually in course of being tested. Furthermore, the range of air conditions within the box are such as to tend to cause serious "working" of timber and rapid depreciation. A copper lining would be an advantage.

The greatest difficulty experienced was the humidity control and it seems evident that the box should be fitted with a fan to provide circulation. With such an addition the salt solutions would probably prove satisfactory. It is necessary to watch these solutions carefully to see that all the water does not evaporate.

Finally, the transference of samples between boxes at high temperatures and humidities should be avoided. Checking is very apt to occur during this procedure, despite the rapidity with which the change is made. On one occasion in these tests, quite a large number of test pieces were ruined in this way. High temperature and high moisture content samples should be conditioned throughout in the testing box; at lower temperatures and moisture contents the transference may be made safely.

6. Acknowledgments.

In the experimental work of the investigations, very considerable assistance was rendered by Mr. Ian Langlands, now Senior Timber Mechanics Officer, Division of Forest Products, who, similarly to the author, was, at this time, abroad as a student financed by the Trustees of the Science and Industry Endowment Fund. Acknowledgment is also made of the helpful advice of Mr. W. Karl Loughborough, of Mr. L. J. Markwardt, and of Mr. M. Y. Pillow, all of the Forest Products Laboratory, Madison, and of the facilities provided by the laboratory authorities.

7. References.

1. Hawley, L. F. U.S. Dept. Agric., Tech. Bull. 248.

2. Pillow, M. Y. "Effect of high temperatures on the mode of fracture and other properties of a hardwood." Wood Working Industries, Oct., 1929.

3. Shewhart. "Significance of an observed range." *Journal of Forestry*, Nov., 1928.

4. Spencer, H. M. "Laboratory Method for Maintaining Constant Humidity." International Critical Tables, Vol. 1, p. 67. (McGraw-Hill Book Co. Inc.)

Radio Research Board—8th Annual Report.

For the year ended 30th June, 1936.

The Radio Research Board of the Council is constituted as follows:—Professor J. P. V. Madsen (University of Sydney), Chairman; Mr. H. P. Brown (Director-General, Postmaster-General's Department); Electrical Commander F. G. Cresswell (Department of Defence); and Professor T. H. Laby, F.R.S. (University of Melbourne). Its previous Annual Report was published in this Journal (Vol. 8, No. 4: November, 1935).—Ed.

1. General.

During the period under review, the investigations of the Board were concentrated on (i) propagation problems, which in turn involved studies of conditions in the ionosphere, and (ii) atmospherics. The last year's operations constitute the third year's activities of the three-year programme towards the cost of which, as mentioned in the last report, the Postmaster-General's Department and the Council for Scientific and Industrial Research are contributing on a 3:1 basis. Arrangements have been made for a continuation of the work on the same basis.

Still further changes in the staff of the Board have taken place. Dr. A. L. Green resigned in September, 1935, to take up an industrial appointment, and Mr. R. W. Boswell resigned in April, 1936, to join the staff of the Research Section of the Postmaster-General's Department. The vacancy left by Dr. A. L. Green has recently been filled by the appointment of Mr. D. M. Myers, a graduate of the University of Sydney, who for the last few years has been obtaining further research experience in Great Britain. He will reach Australia in about October, 1936, and will be located at the University of Sydney. Mr. A. F. B. Nickson and Mr. F. G. Nichols have been appointed on a part-time basis to carry out much of the atmospherics work previously undertaken by Mr. Boswell.

2. Work on Fading and the Ionosphere.

Since practically all radio communication on wavelengths below 100 metres is by reflection from one or other of the reflecting layers of the ionosphere, the direct importance of a knowledge of the diurnal and seasonal changes of conditions in these regions is obvious.

In addition, the radio methods developed for ionospheric observation enable many deductions to be made concerning the nature, pressure, temperature, and ionisation of the gases present in the region between 50 and 250 km. above the earth—matters which are of great importance to the meteorologist.

The work of the Radio Research Board in this sphere is centred in the University of Sydney and its progress has been, technically, towards ever-increasing accuracy and comprehensiveness of the information obtained, combined with careful and exhaustive examination

of all data as they become available so as to trace out all the implications. Considerable advances have been made both in technique and theory during the last twelve months.

The frequency-change method of investigation which has been in use for several years has served a very useful purpose, but it has two main disadvantages. It is prodigal in labour and materials for the amount of information obtained, and the records become very difficult to interpret if multiple echoes are present, as is very frequently the case on wavelengths below 200 metres.

The first disadvantage has been largely obviated by a modified arrangement in which a faster frequency-change is employed and the resultant fringe pattern appears on the screen of a cathode-ray tube. Its appearance and changes can thus be observed directly and photographed when necessary.

For the separation of multiple echoes, however, some form of the pulse method is preferable, and this system has been developed and improved to a very advanced stage. The first type of apparatus makes a continuous record, on motion picture film, of the time delay in arrival of all echoes on any one wavelength. From this record, the heights of the reflecting layers can be deduced. For this work, transmitters have been constructed to send out pulses of very short duration at regular intervals, and special receivers and recording apparatus designed and brought into use. Modifications at the receiver enable the intensities of the echoes also to be measured; some additional information is thus obtained.

The next advance was to enable the transmitter and receiver to be varied rapidly through a large range of frequencies so that the range of frequencies reflected by each layer can be determined at any time. From the frequency which penetrates a layer, the ionisation density can be deduced. In the earlier apparatus, the frequency change was by steps, but in the latest equipment it takes place continuously and automatically. Incidentally, the records obtained give direct information as to the best frequencies for transmission at given times.

A further advance, in this case an original development, is a receiving system which combines most of the merits of the frequency-change and pulse methods. In this system, each echo produces on the cathode-ray tube screen an ellipse which indicates the intensity and state of polarisation, including the sense of rotation. The apparatus now in use is therefore capable of giving very comprehensive data on ionospheric conditions.

The examination of data obtained has already led to important deductions concerning the constitution of, and conditions in, the ionosphere. Further, the information obtained from the radio work has enabled order to be found in what hitherto appeared to be conflicting results from other sources of evidence such as meteor trails, aurorae, and luminous night clouds. The results of these considerations have been embodied in a paper read before the Royal Society in London (see *Proc. Roy. Soc.* A., **154**: 755, 1936). A further paper embracing more recent results is in preparation.

Briefly, the work done to date has led to the following findings:—

The F region of the ionosphere is found to be at temperatures of the order of 1,000°C. These high temperatures exist both in summer and winter, although during winter nights a limited amount of cooling occurs.

The high temperatures thus found are attributed mainly to the absorption of solar ultra-violet light by ozone, which is present in a concentration of about 1 in 10,000. The cooling occurring on a winter night is attributed to radiation by water vapour in a concentration of 1 in 6,000.

The atmosphere is found to be almost completely mixed at the level of the ionosphere, and consists mainly of molecular nitrogen and atomic oxygen.

It is found that the free electrons in the ionosphere disappear by attachment to neutral oxygen particles very quickly, so that none would be present a few minutes after sunset but for the presence of a counterbalancing detaching agent. This agency is found to be the energy of recombination of atomic oxygen, which sets free attached electrons in the process of recombining into molecular oxygen. The high energy electrons thus liberated are able to excite the green line spectrum of the night sky. These views are supported by consideration of Lord Rayleigh's measurements of the absolute intensity of the green line, and of its seasonal and diurnal variations, which follow closely the corresponding variations of ionisation in the F region.

Consideration of the temperatures below the 100 kms. level shows a maximum temperature of 175°C. at 60 kms., and a minimum of minus 113°C. at 82 kms. The low temperature at this level, in conjunction with the presence of water vapour, permits the separation of ice crystals, thus giving rise to luminous night clouds.

The ionisation densities in the E and F regions are found to correlate directly, and the height of the F region indirectly, with the barometric pressure at the ground. This correlation is attributed to the temperature changes occasioned by changes in ozone concentration.

In addition to the direct work of the Board's officers, some useful combined work with kindred branches of the University of Sydney has resulted. The assistance of Professor V. A. Bailey of the Department of Physics was mentioned in the previous report, particularly in connexion with his paper on the influence of electric waves on the ionosphere and the Luxemburg effect.

Mr. Godfrey, in collaboration with Mr. W. L. Price of the Sydney Technical College, following up a line suggested by Dr. Martyn, has developed some interesting mathematical results concerning temperatures in the upper atmosphere which he has embodied in a paper entitled, "Radiation Equilibrium above 200 kilometres in the Upper Atmosphere," which he presented to the Conference of Australian physicists which met in Sydney in May, 1936. Following on some work of the Board's officers, Mr. R. N. Morse has developed a new method of investigating transient phenomena in electrical circuits.

A good deal of special auxiliary apparatus has been developed in the course of the year's work, e.g.,

A temperature-compensated low-frequency oscillator of very good frequency stability.

A new type of harmonic analyser.

A new type of calibrator for C.R.O. time scales.

Thyratron time bases.

3. Work on Atmospherics.

The close connexion found between moving sources of atmospherics and cold fronts over the Australian Bight in the summer of 1934-5 suggested a continuation of the work, to determine the value of atmospherics direction-finders for weather forecasting, especially for south-eastern Australia. The Commonwealth Weather Bureau has kindly agreed to co-operate in this work, and the joint programme has been in operation since August, 1935. It is proposed to continue it for one year from that date.

A narrow-sector directional recorder has been installed at Hobart and has been in operation since October, 1935. Further adjustments have been made to the Watheroo and Canberra recorders, so that it is now possible to locate most of the major sources of atmospherics over the Australian Bight, south-eastern Australia, and the Tasman Sea over the whole 24 hours. (Cathode-ray direction-finders, at Laverton and Canberra, are still operated in the daytime). The meteorological analysis is carried out entirely by the Weather Bureau.

In contrast to the previous spring and summer, few sources were observed in the Australian Bight, and few of these persisted more than 24 hours and moved across south-east Australia. It thus appears that during the year under review the majority of cold fronts over the Australian Bight were unaccompanied by (sea) thunderstorms, so that the number of occasions when information of possible use for forecasting was obtained was small. More sources were observed over the Tasman Sea, which suggests that the method may on occasions be of more value for New Zealand weather forecasting.

In assessing the usefulness of the method for forecasting, it is even more important to know what percentage of sea sources are associated with well-marked fronts. An entirely suitable criterion of "association" is lacking, but, judging from proximity (allowing for errors in location), between 50 and 60 per cent. of sea sources appear to be associated with well-marked fronts, mostly cold fronts, for the Australian Bight and Tasman Sea south of 30°S. The analysis of some earlier data has shown that the percentage is considerably lower for more northerly sea areas. Final conclusions have not yet been reached.

Another aspect of this investigation is the possibility of thunderstorm warnings to aircraft, particularly on air routes over sea. On a few occasions, it has been possible to communicate useful information to Essendon (Melbourne) Aerodrome regarding the location of thunderstorms near air routes. This information has always been derived from cathode-ray direction-finders, and it would appear that

the most promising application of the method is in the use of cathode-ray direction-finders for the combined purpose of locating the position of the aeroplane and of thunderstorms.

An investigation has been commenced with the object of determining the total energy radiated (in the "radio" portion of the spectrum) by the average lightning flash. The necessary apparatus is still under construction and involves the putting together of a special amplifier to give constant amplification over a very wide range of frequencies. In addition to the total energy radiated, it is hoped to obtain some additional information regarding the wave-form of atmospherics, on which subject some discrepancies appear to exist between the results of previous investigations.

4. Publications.

The following publications have been made during the past year as a result of the investigations carried out by the officers of the Board and by independent investigators who have been closely associated with these officers.

(a) Publications of the Council for Scientific and Industrial Research.

1. *Bulletin* 95.—"Radio Research Board: Report No. 9." (1) "A Study of the Magneto-Ionic Theory of Wave Propagation by Means of Conformal Representation," by V. A. Bailey, M.A., D.Phil., F.Inst.P. (2) "Dispersion and Absorption curves for Radio Wave Propagation in the Ionosphere according to the Magneto-Ionic Theory," by D. F. Martyn, Ph.D., A.R.C.Sc., F.Inst.P. (3) "A Temperature-Compensated Dynatron Oscillator of High Frequency Stability," by J. H. Piddington, B.Sc., B.E. (4) "The Amplification of Programme Transients in Radio Receivers," by Geoffrey Builder, Ph.D., F.Inst.P. (5) "A Multi-Range, Push-Pull, Thermionic Voltmeter," by Geoffrey Builder, Ph.D., F.Inst.P. (6) "The Graphical Solution of Simple Parallel-Tuned Circuits," by Geoffrey Builder, Ph.D., F.Inst.P. (7) "An Electrical Harmonic Analyser of the Fundamental Suppression Type," by J. H. Piddington, B.Sc., B.E.

2. *Bulletin* 100.—"Radio Research Board: Report No. 10." (1) "A Directional Recorder for Atmospherics," by W. J. Wark, M.Sc., R. W. Boswell, M.Sc., and H. C. Webster, Ph.D., F.Inst.P. (2) "Observations of Atmospherics with a Narrow Sector Directional Recorder at Canberra," by G. H. Munro, M.Sc., A.M.I.E.E., W. J. Wark, M.Sc.. and A. J. Higgs, B.Sc. (3) "Characteristics and Distribution of Sources of Atmospherics," by G. H. Munro, M.Sc., A.M.I.E.E., W. J. Wark, M.Sc., and A. J. Higgs, B.Sc. (4) "Sources of Atmospherics Over the Tasman Sea," by R. W. Boswell, M.Sc.

(b) Other Publications.

1. "Interaction of Radio Waves," by V. A. Bailey, M.A., D.Phil., and D. F. Martyn, Ph.D., A.R.C.Sc. *Nature,* 135; 585, 1935.
2. "A Receiver Discriminating between Right- and Left-handed Circularly Polarised Wireless Waves," by O. O. Pulley, Ph.D., B.E. *Phys. Soc.* 47, 1098, 1935.
3. "Modulation Frequency-Change Technique for Ionospheric Measurements," by Geoffrey Builder, Ph.D., F.Inst.P., and A. L. Green, Ph.D. *Phys. Soc.* (6), 47, 1935.

4. "The Delineation of Selectivity Curves," by W. G. Gordon, B.Sc. *Rad. Rev.*, Nov., 1935.

5. "Aircraft Radio Communication and Navigation," by H. B. Wood, B.Sc., B.E. *Rad. Rev.*, Sept., 1935.

6. "Design of a Simple Linear Time-Base for the Cathode Ray Oscillograph," by O. O. Pulley, Ph.D., B.E., and A. H. Mutton. *Rad. Rev.*, November, 1935.

7. "Wireless Direction-Finding and its Application," by G. H. Munro, M.Sc., A.M.I.E.E. *Australasian Engineer*, Aug., 1935.

8. "The Ionosphere and its Influence upon the Propagation of Radio Waves," by J. P. V. Madsen, B.E., D.Sc. Macrossan Lectures, University of Queensland, 1935.

5. Acknowledgments.

Once again, acknowledgment is due to a number of organisations and individuals for the valuable co-operation they have furnished. The help of the Postmaster-General's Department and of the Universities of Melbourne and Sydney has been continued on the previous lines. The Department of Defence, too, has afforded help in several ways, notably by the loan of apparatus and the accommodation of equipment at Laverton (Victoria) and Liverpool (New South Wales). The Commonwealth Solar Observatory at Mt. Stromlo, and the Watheroo Magnetic Observatory of the Carnegie Institution are also co-operating most helpfully in connexion with the work on atmospherics. The Commonwealth Meteorological Bureau has also furnished meteorological data at all times, and, at the commencement of the period under review, arranged to co-operate in a thorough test of the possible value of the Board's atmospheric work from a meteorological point of view. This work is still in progress.

"Firing"—A Heritable Character of Wheat

*By J. R. A. McMillan, B.Sc.Agr., M.S.,**

Summary.

1. A character of wheat designated "firing", in which the leaves and sheaths of "fired" plants die about flowering time, is reported.

2. No parasite or peculiar environmental factor has been found to be associated with the condition. It appears to be due to a physiological breakdown, the nature of which is unknown.

3. Predisposition to the condition is inherited, "firing" being dominant to normal.

4. In three crosses Cadia-Shepherd, Cleveland-Shepherd, and Federation-Shepherd, the inheritance can be accounted for by the interaction of three complementary pairs of allelomorphic genes $F_a f_a$, $F_b f_b$, $F_c f_c$. At least one of each of these pairs must be present in the dominant form to condition the expression of "firing". Occasionally, a genotype for "firing" fails to develop this character before the usual onset of straw colour changes.

5. Shepherd has one recessive and two factors dominant, e.g., $f_a f_a$, $F_b F_b$, $F_c F_c$, while Cadia, Cleveland and Federation have the allelomorphs of these, being $F_a F_a$, $f_b f_b$, $f_c f_c$.

6. The probable constitution of a number of other varieties is given.

1. Introduction.

During the course of an examination of certain F_1 material grown at Canberra in 1931, it was noticed that in some crosses all of the F_1 plants showed abnormal characters. The F_2 from these crosses segregated for the same type, together with normal plants.

Detailed examination showed that plants possessing this abnormal character were indistinguishable from normal ones up to the pre-flowering stage, when the uppermost laminae of affected plants began to die as a whole—not from the tip backwards. Death was fairly rapid, but for some days the laminae retained their usual shape and remained quite stiff. The first colour change was from the normal green to a greenish-grey, which was followed by a change to a dull brownish-red and then to the ordinary straw colour. The sheaths died off later than the laminae and changed immediately from green to straw colour. When all of the leaves (laminae and sheaths) were dead (straw colour), the stems and ears were still green, the ears being greener than the stems. Usually, these plants produced small stunted ears, flowered later than normal plants, and produced shrivelled viable seed, but some did not bear any ears. Some of them were as much as twelve inches shorter than the normal, while others were the same height. In some the root system was weak, for they were much more easily uprooted than normal plants. No other differences were noted. The development of this character in some segregates was much more pronounced than in the F_1, while in others it was less. In most cases there was no difficulty in distinguishing them from normal plants at flowering time, but occasionally there was a tendency for the expression

* Senior Geneticist, Division of Plant Industry.

of this character to be delayed until well after flowering, when it was difficult to distinguish them from normal plants undergoing straw colour changes at the same time.

To this phenomenon the term "firing" was given as best covering the symptoms presented, and affected plants were described as "fired". For illustrations of "fired" as compared with normal plants see Plates 3 and 4.†

"Firing" did not appear to be due to plants growing in any particular locality, since "fired" and normal plants were found growing within two inches of one another and often with their culms intermixed (see Plate 4). It occurred in "grass clump" as well as "non grass clump" plants. No evidence was found of the condition being associated with any parasite. A special search* was made for *Bacterium translucens* var. *undulosum,* but it was not found. As it gave one the impression of a scalding or firing of the plant, it was first thought that lack of water may have been the cause, but repeated heavy irrigations did not prevent or cure the condition. It appeared to be a physiological breakdown at the pre-flowering stage of the plant's development. Just what the nature of this breakdown was, or the immediate cause of it, has not been determined.

"Fired" plants did not occur at random throughout the field as a whole, but were confined to the progeny of certain crosses. This indicated that predisposition to the condition was inherited. It was decided to investigate the mode of inheritance and to determine, if possible, the genetic constitution of the "fired" plants and that of their parents.

2. Materials and Field Methods.

The material used for the investigation consisted of some 19 varieties. Crosses between some of these had been made previously, but others were made after the discovery of "fired" plants. All crosses were carried through the F_2 generation, and three were taken on to the F_4. The F_1's of these three crosses were back-crossed with each of their parents. All plants were grown under field conditions on typical wheat soil, and in the normal wheat-growing season, the seeds being sown approximately half a link apart (except the F_4 when the spacing was 2 inches) in rows 2 links apart.

The plants were classified and counts made just before the onset of the usual straw colour changes associated with ripening.

3. Data.

The occurrence of "fired" and normal plants was recorded in the following populations. Actual counts of each type were made in F_1, F_2, F_3, and the back-crosses, but in the F_4, records were taken only as to whether or not the families segregated or bred true:

1. F_1 (*a*) Crosses which produced "fired" plants in the F_1.
   (*b*) Crosses with Shepherd which did not produce "fired" plants in F_1.
2. F_2 of crosses which segregated "fired" types in F_2 (Table 1).
3. F_3 of the crosses Cadia-Shepherd (Table 2), Cleveland-Shepherd and Federation-Shepherd.

* Made by Dr. W. L. Waterhouse, of the University of Sydney.

† Facing page 316.

4. F_4 of normal derivatives from segregating F_3 families.
5. Back-crosses of the F_1 of Cadia x Shepherd, Cleveland x Shepherd, and Federation x Shepherd to each of their parents.

All crosses, which produced "fired" plants in the F_1, had Shepherd as one parent. The other parents were Bena, Bobin, Cadia, Cleveland, Colorado No. 50, Federation, Tuela, Turvey, Wandilla, and Yandilla King. Many of the crosses were made both in the direct and reciprocal manner.

Varieties which, when crossed with Shepherd, did not produce "fired" plants in either the F_1 or F_2 were Bomen, Caliph, Canberra, Dicklow, Jonathan, Minister, Thew, and Waratah.

4. Analysis and Discussion.

General.

For testing the data against various ratios, an 0.05 level of significance was adopted when using the normal curve (P determined by the D/S.E. method), and an 0.025 when using Warwick's tables. In the latter case P_w was determined for one tail only. Unless the deviations from the calculated gave probabilities smaller than those stated above, they were not considered to be significant.

Many of the families raised for this investigation had less than 50 individuals. In such cases Warwick has pointed out that the method of determining the probabilities of the deviations from Mendelian ratios on the basis of the normal curve is incorrect, and that the binomial expansion should be used. In order to save calculation he has prepared tables for populations of 1 to 50 for some of the more common Mendelian ratios. These tables have been used in this paper for families of 50 or less to determine the value of the probability of getting the ratio obtained or one with a greater deviation in one direction only. Tables for ratios of 27 : 37 are not given, but as this is very similar to the reverse of the 9 : 7 the latter was used. Thus the probability of obtaining 19 "fired" to 24 normal (as in Shepherd x Wandilla F_2 Table 1) when a ratio of 27 : 37 was expected, was determined by entering Warwick's table for 43 individuals and a ratio of 9 : 7 at 24 dominants to 19 recessives—the reverse of 19 "fired" to 24 normals.

A preliminary examination of the data suggests that "fired" is dominant to normal, and, unless the inheritance is somewhat complex, normal plants being recessive would be expected to breed true. But when progenies were raised from normal derivatives, of crosses segregating "fired" types, it was found that a few, viz., 5/60 in the F_3, and 5/97, 3/100, and 12/94, in different F_4 generations, did not breed true to normal but segregated "fired" plants. The small proportion of types behaving thus suggests, in the first place, that a few plants possessing a genotype for "firing" do not develop "fired" phenotypes. There was some evidence for this because, as was pointed out in the introductory remarks, in some cases there was a tendency to delay the expression of the "fired" character until just prior to the commencement of straw colour changes associated with ripening. It was possible that others were delayed even further, and then, of course, it would be impossible to differentiate "fired" and normal types which had entered the usual straw coloured change stage. The delay could be due either to genetic modifying factors or to environment—using

environment in its widest sense to include all factors and conditions operating except those in the germ plasm. If genetic factors were concerned, it was unlikely that they were major ones, and hence it was assumed, pending further data, that normal plants which segregated "fired" types were of the same genetic constitution for major factors as "fired" plants. Thus most of the plants classified as normal had the genotype for normal, but a few had that for "firing."

Before any comparison of the data with various ratios was undertaken, the proportion of "fired" to normals was corrected on the basis of the breeding behaviour of the normals. Thus in each F_2 carried on, 20 normals were taken, and of these 1, 2, and 2, in the crosses Cadia-Shepherd, Cleveland-Shepherd, and Federation-Shepherd respectively, segregated "fired" types. As these numbers were small it was felt that a better estimate would be obtained by combining them. Each of the F_2's in these three crosses was corrected therefore, by reducing the number of normals by 5/60 and adding these to the number of "fired."

The F_2.

The fact that none of the parents developed "firing," whereas this condition did occur in the F_1, indicates that "firing" is dominant to normal and is determined by complementary factors.

For the F_2, 14 crosses were carried on and of these all but one produced fewer "fired" than normal plants (see Table 1), which indicates that at least three complementary factors were operating. Hence in the first place an hypothesis, based on the interaction of three such factors, was tested. On this basis the F_2 ratio would be 27 "fired" to 37 normal.

For the first three crosses listed in Table 1 corrected data were used in the comparison with the expected, but for the remaining crosses, grown in different years, no information was obtained on which to base an estimate for correction, and so the observed data were used. Of the 14 different F_2 results recorded, all except one, Colorado No. 50 x Shepherd, fall well within the 0.05 level of significance and the deviations can be regarded as random. For the exceptional cross, P equals 0.015 and the odds are about 66 : 1 against such a deviation being due to chance alone. However, this is really only one case out of 14, and the probability of obtaining such a deviation, at least once in 14 times, is 0.19 (Tippett, p. 53). The odds are only about 4 : 1, and the deviation cannot be regarded as significant. The F_2 data of this cross will also fit a 9 : 7 ratio as is shown at the bottom of the table.

The F_3.

To determine the accuracy of the F_3 classification, an F_4 was raised from normal plants taken at random from segregating F_3 families. From 94 to 100 of such normals were carried on into F_4 in each of the three crosses, and of these, 5/97, 3/100, and 12/94 segregated in Cadia x Shepherd, Cleveland x Shepherd, and Federation x Shepherd respectively. The F_3 data for each cross was corrected on the basis of its F_4 behaviour. Thus in Cadia x Shepherd the number of normals was reduced by 5/97 and this number transferred to the "fired" class.

On the basis of the three factor hypothesis all of the normal F_2 plants would be expected to breed true to normal in F_3 except an occasional one which would segregate because it failed to develop

TABLE 1.—F_2 OF CROSSES PRODUCING "FIRED" PLANTS.

Pedigree.	Cross.	Observed. T*.	Observed. F* : N*.	Corrected. F : N.	Calculated on a basis of a ratio of 27 : 37. F : N.	D.	S.E.	D/S.E.	P.
	1932.								
Wx 411a2	Cadia x Shepherd	145	57 : 88	64·33 : 80·67	61·17 : 83·83	± 3·16	5·95	0·53	0·60
,, 446a3	Cleveland x Shepherd	168	60 : 108	69·00 : 99·00	70·87 : 97·13	± 1·87	6·40	0·29	0·77
,, 492a1	Federation x Shepherd	124	44 : 80	50·67 : 73·33	52·31 : 71·69	± 1·64	5·50	0·30	0·76
	1933.								
,, 649b10	Shepherd x Bobin	208	88 : 120	† : †	87·76 : 120·24	± 0·24	7·12	0·03	0·98
	1935.								
,, 411c1	Shepherd x Cadia	185	83 : 102	† : †	78·05 : 106·95	± 4·95	6·72	0·74	0·46
,, 1177a3	Cadia x Shepherd	213	99 : 114	† : †	89·86 : 123·14	± 9·14	7·20	1·27	0·20
,, 446c5	Cleveland x Shepherd	184	84 : 100	† : †	77·63 : 106.37	± 6·37	6·70	0·95	0·34
,, 492b1	Shepherd x Federation	210	81 : 129	† : †	88·60 : 121·40	± 7·60	7·16	1·06	0·29
,, 1163a3	,, x Wandilla	43	19 : 24	† : †	18·14 : 24·86	± 0·86	..	..	0·54‡
,, 1166a1	,, x Yandilla King	55	27 : 28	† : †	23·20 : 31·80	± 3·80	3·66	1·04	0·30
,, 1170a2	,, x Turvey	201	86 : 115	† : †	84·80 : 116·20	± 1·20	7·00	0·17	0·47
,, 1188a2	,, x Tuela	92	39 : 53	† : †	38·81 : 53·19	± 0·19	4·77	0·04	0·97
,, 1233a1	Bena x Shepherd	50	23 : 27	† : †	21·10 : 28·90	± 1·80	3·48	0·55	0·58
,, 1121a4	Colorado No. 50 x Shepherd	197	100 : 97	† : †	83·11 : 113·89	± 16·89	6·93	2·44	0·015
					Ratio of 9 : 7				
,, 1121a4	,, ,, ,, ,,	197	100 : 97	† : †	110·81 : 86·19	± 10·81	6·97	1·55	0·12

* T = Total, F = Fired, and N = Normal.

† No data available for correction. Observed data are compared with the calculated.

‡ From Warwick's Table, probability for one tail only.

"firing" before the straw colour change. The "fired" F_2, together with those normal plants which segregated "fired" types in F_3, should breed true or segregate in the ratios of 3 : 1, 9 : 7, and 27 : 37 "fired" to normal, in the proportion of 1 : 6 : 12 : 8 respectively.

To determine the frequency of the various types of breeding behaviour in the F_3, the corrected figures were compared with the ratios 3 : 1, 9 : 7, and 27 : 37, and P (from Pearson) determined for families greater than 50, and P_w from Warwick's tables for other families.

If the expected frequency of the various types of F_3 behaviour were the same, then the criterion which would be used to group them would be the probability of obtaining such deviations from the various ratios. A family would be grouped in the class with which it gave the greatest probability. But, since the expected frequency of the various ratios is different, viz., 6 : 12 : 8, such procedure would give an unfair advantage to the type of behaviour with the greatest frequency (Tingey 1928), and some allowance should be made for this expectancy. Thus any one segregating family would have a probability of 6/26, 12/26, or 8/26 of belonging to the mono-, di-, or tri-hybrid group respectively, and hence the chance of getting a particular deviation in the mono- as compared with the di-hybrid is in the ratio of 6/26 : 12/26. Allowance can be made easily by weighting the probability according to the expectancy. For example, suppose a particular family when compared with a 3 : 1 and 9 : 7 ratio gives probabilities of 0.14 and 0.09 respectively. If it is required to classify it in accordance with the hypothesis, then these should be weighted in the proportion of 6/26 : 12/26 which gives 0.84/26 : 1.08/26 and it would be classified in the 9 : 7 group.

Hence in classifying the F_3 families reported in this paper the probabilities either derived from Pearson for families over 50 or from Warwick (one tail of distribution only) for others have been weighted in accordance with the expectancy.

The data were corrected, as outlined above, to the second decimal place, but Warwick's tables are only applicable for whole numbers. Interpolation would not be reasonably accurate, especially in the small populations, so it was decided, when determining the probability by Warwick's tables, to carry the correction to the nearest whole number only and thus for the probability for a family with a corrected proportion of 19.68 : 18.32 the table was entered at 20 : 18.

The data of those families which segregate can be combined, and the combined results compared with the expected. The calculated ratio for this purpose is based on equal populations in each family. By expressing the observed individual ratios as percentages, summing and averaging, the combined ratio is found to be 56.25 normals to 43.75 "fired."

In comparing the observed results with this ratio, two methods can be used. Either the corrected figures for each family can be summed and the totals used, or the corrected figures in each family can be expressed as percentages and the percentages averaged. If there is no association between the number of individuals in the family and the ratios, the former is better. The latter method would overcome such a difficulty, but it would appear to give too much weight to a family of

few individuals, e.g., by this method a family of 5 would be considered to give just as accurate a result as one of 150. As this was obviously unfair and as there was no evidence of any association between fertility and type of behaviour, the first method of summing the corrected proportions of each family was considered better.

(i) *Cadia* × *Shepherd.*

Twenty F_2 normal plants were carried on to the F_3 and of these 19 bred true to normal and one segregated. For further analysis this segregating family was considered as having been derived from a "fired" F_2 plant.

Of 26 families raised from "fired" F_2 plants, one bred true and 25 segregated (Table 2). The calculated number to breed true is slightly less than one so that the agreement is good.

TABLE 2.—F_3 FROM "FIRED" AND NORMAL F_2 PLANTS IN CADIA × SHEPHERD—Wx 411a: DATA OBSERVED, AND CORRECTED ON BASIS OF F_4 BEHAVIOUR.

F_2.		F_3.				
Ped. No. Wx 411a.	Classified as—	Observed.		Corrected.		Ratio.
		T.	F : N.	F : N	% N.	
2 96	F	13	12 : 1	12·05 : 0·95	7·31	3 : 1
9	N	16	13 : 3	13·15 : 2·85	17·81	,,
144	F	20	16 : 4	16·21 : 3·79	18·95	,,
15	,,	10	8 : 2	8·10 : 1·90	19·00	,,
102	,,	38	28 : 10	28·52 : 9·48	24·95	,,
20	,,	15	11 : 4	11·21 : 3·79	25·27	,,
127	,,	64	43 : 21	44·08 : 19·92	31·12	,,
99	,,	137	90 : 47	92·42 : 44·58	32·54	,,
86	,,	26	17 : 9	17·46 : 8·54	32·85	9 : 7
139	,,	13	8 : 5	8·26 : 4·74	36·46	,,
105	,,	5	3 : 2	3·10 : 1·90	38·00	,,
54	,,	31	18 : 13	18·67 : 12·33	39·77	,,
114	,,	38	21 : 17	21·88 : 16·12	42·42	,,
37	,,	101	55 : 46	57·37 : 43·63	43·20	,,
44	,,	153	82 : 71	85·66 : 67·34	44·01	,,
27	,,	6	3 : 3	3·15 : 2·85	47·50	,,
3	,,	88	43 : 45	45·32 : 42·68	48·50	,,
47	,,	120	57 : 63	60·25 : 59·75	49·79	,,
94	,,	60	28 : 32	29·65 : 30·35	50·58	,,
145	,,	30	14 : 16	14·82 : 15·18	50·60	,,
71	,,	47	20 : 27	21·39 : 25·61	54·49	27 : 37
19	,,	5	2 : 3	2·15 : 2·85	57·00	,,
97	,,	32	12 : 20	13·03 : 18·97	59·28	,,
43	,,	8	3 : 5	3·26 : 4·74	59·25	,,
12	,,	4	1 : 3	1·15 : 2·85	71·25	,,
42	,,	11	11 : —	— : —	..	..
Total for segregating families ..			..	632·31 : 447·69	..	..
Average for segregating families..			..	58·55 : 41·45	40·08	

N. In addition, 19 F_2 normal plants bred true to normal in the F_3.

P for families greater than 50 has been determined from the normal curve for deviations in both directions; for families not greater than 50, P has been determined from the binomial distribution for deviations in one direction only.

The correction factor for the F_3 families of this cross was 5/97. Figures thus obtained were compared with the expected ratios 3:1, 9:7, and 27:37. In all cases except one a good fit was obtained with one or other of the ratios. With the exception P for a 3:1 was 0.04, and for a 9:7 was 0.01. The odds are only 24:1 against it being a 3:1 and 99:1 against the 9:7.

Weighting the probabilities, as outlined above, and then classifying the F_3 families according to the ratios they fit best, it is seen that there are 8, 12, and 5 for 3:1, 9:7, and 27:37 respectively. On comparing this with the calculated, X^2 is found to be 1.8212, and P lies between 0.50 and 0.30, so that the fit is good.

Combining the corrected data from the segregating families, it is found that the number of "fired" to normal is 632.31:447.69 (Table 2). Compared with the expected D/S.E. is found to be 1.52, and the fit is good.

(ii) *Cleveland* × *Shepherd.*

Twenty normal F_2 plants were grown into F_3 and of these 18 bred true to normal and 2 segregated. The two latter families were included with those from "fired" F_2 plants for further analysis. Thus 25 such families were raised, of which a proportion slightly less than one was calculated to breed true to "firing". Actually none did so but the deviation is very small. As one family produced only 2 individuals it was not considered further.

The correction factor applied to the F_3 data for this cross was 3/100. The corrected figures give good fits with one or other of the ratios 3:1, 9:7, or 27:37 with the possible exception of one family where P_w for an individual sample is 0.0163. This is only one sample in 9 for ratios of 27:37, and for a deviation as large as this to occur at least once in 9 times P_w is 0.1377 (Tippett, p. 53). The deviation is therefore not inconsistent with the hypothesis.

To classify the families for various types of breeding behaviour the probabilities were weighted. With the exception of two families, the classification is the same without weighting, but these become transferred from the 3:1 and 27:37 classes to the 9:7 class. This gave 2, 13, and 9 in the 3:1, 9:7, and 27:37 classes respectively. Compared with the calculated proportion, it is found that X^2 equals 2.9503 and P lies between 0.20 and 0.30.

Combining the corrected data from the segregating families, it is found that the number of "fired" to normal is 492.75:509.25. Compared with the calculated it is found that D/S.E. is 4.51, which is a very bad fit indeed. No explanation is offered at present for this wide deviation.

(iii) *Federation* × *Shepherd.*

Twenty normal F_2 plants were grown into F_3 and of these 18 bred true and 2 segregated. The latter have been included with those from "fired" F_2 plants, which segregated, for further analysis. Thus 18 such families were raised of which the proportion calculated to breed

true to "firing" is 0.67. One family produced only three plants all of which were "fired". The number of individuals, however, is too small to consider it homozygous. Even rejecting this, the deviation from the expected 0.67 is small.

The correction factor applied to the F_3 of this cross was 12/94, and the figures thus obtained give good fits with one or other of the three ratios 3 : 1, 9 : 7, and 27 : 37. Classifying the families according to behaviour—using weighted probabilities as for other crosses—one was transferred from the mono- to the di-hybrid class, the others remaining unaltered. The classification was 2, 13, and 2 for mono-, di- and tri-hybrid ratios respectively, which when compared with the expected, gave X^2 of 6.3139, P being between 0.05 and 0.02. The fit is not very good, but considering this is one of three crosses it would be reasonable.

The combined corrected data from segregating families gave 585.67 "fired" to 469.33 normals. From a comparison with the calculated it is seen that D/S.E. is 0.48 and the fit is quite good.

(iv) *The three F_3's combined.*

The results of classifying the F_3 segregating families according to ratios were combined and compared with those calculated (see Table 3). From this it is seen that P lies between 0.20 and 0.10 and the fit is good.

TABLE 3.—COMPARISON OF COMBINED OBSERVED WITH CALCULATED FREQUENCY OF F_3 RATIOS IN SEGREGATING FAMILIES IN THE THREE CROSSES CADIA-SHEPHERD, CLEVELAND-SHEPHERD AND FEDERATION-SHEPHERD.

		Observed.			(o).	Calc. (c).		
Ratio. F : N.	Calculated per 26.	Cadia x Shepherd.	Cleveland x Shepherd.	Federation x Shepherd.	Total.		o−c	$\frac{(o-c)^2}{c}$
3 : 1	6	8	2	2	12	15·23	−3·23	0·6850
9 : 7	12	12	13	13	38	30·46	+7·54	1·8664
27 : 37	8	5	9	2	16	20·31	−4·31	0·9146
Total ..	26	25	24	17	66	66	..	3.4660

$X^2 = 3.4660$ and P lies between 0.20 and 0.10.

Sixty-six families segregated and one bred true to "firing". The calculated number to breed true being about 2.5 the deviation therefore is not large.

The homozygous family was excluded from this test, because the expected number is only about 2.5, and classes with an expected frequency of less than 5 should be combined with others or excluded from a chi square test (Fisher, p. 86).

The combined corrected data gave 1710.73 "fired" to 1426.27 normals which, when compared with the calculated, shows D/S.E. to be equal to 1.94, and is therefore just above the 0.05 level of significance.

Conclusions from F_1, F_2, and F_3.

With the possible exception of the combined F_3 data from segregating families in the cross Cleveland-Shepherd the analysis of the F_2 and F_3 does not show any serious inconsistencies with a three complementary factor hypothesis. Until further evidence is available this exception is regarded as a very wide random deviation. The three pairs of factors operating can be designated $F_a f_a$, $F_b f_b$, $F_c f_c$. "Fired" plants would have at least one of each pair dominant and be F_a—F_b—F_c—, while all other genotypes would condition the development of normal plants. The F_1 would be $F_a f_a$, $F_b f_b$, $F_c f_c$. Each parent must have at least one pair recessive, Shepherd could have one or two pairs recessive, and the other parents, which produce "fired" F_1 when crossed with Shepherd, would have two or one pairs recessive respectively. The actual constitution of the factors in these varieties can be determined by back-crosses.

Back-Crosses.

When "fired" F_1 plants were back-crossed to normal varieties, the expected back-cross ratio was 1 "fired" to 1 normal if the variety had only one pair recessive, and 1 "fired" to 3 normals if there were two recessive pairs.

The results of back-crosses with Shepherd are recorded in Table 4(*a*). Cadia-Shepherd and Federation-Shepherd fit a 1:1 ratio quite well, but with Cleveland-Shepherd the deviation is somewhat more than expected for an individual result, D/S.E. being 2.10 and P equal to 0.036. But when considered as one of 3 samples P equals 0.104 (Tippett). The combined data give a satisfactory fit with a 1:1.

Backcross data with varieties other than Shepherd are recorded in Table 4(*b*). Those with Cadia and with Federation fit a 1:3 ratio, but in the case of Cleveland D/S.E. is again high at 2.83, P for one of three samples being 0.014. No explanation can be offered at the present juncture of these two deviations of Cleveland back-crosses except that such may occur occasionally due to sampling errors. The combined data from the three sets of back-crosses fit a 1:3 ratio. Assuming then that the deviations with Cleveland in each type of back-cross are due to random errors, there being no other evidence to the contrary, then Shepherd would have one recessive and two dominant pairs, while Cadia, Cleveland, and Federation would have two recessives and one dominant, these being allelomorphs of the genes in Shepherd. The genotype of Shepherd would be $f_a f_a$, $F_b F_b$, $F_c F_c$, and of Cadia, Cleveland and Federation, $F_a F_a$, $f_b f_b$, $f_c f_c$.

TABLE 4.—DATA FROM BACK-CROSSES OF F_1 TO —(*a*) SHEPHERD.

Back-cross.	Observed.		Calculated on ratio of 1 : 1	D.	S.E.	D/S.E.
	F : N.	F : N.	F : N.			
Shepherd 873*b* x (Shepherd 873*b* x Cadia 155*a*) F_1	5 : 5					
,, ,, ,, ,, ,, ,, ,,	8 : 5					
,, ,, ,, ,, ,, ,, ,,	3 : 4					
(Shepherd 873*b* x Cadia 155*a*) F_1 x Shepherd 873*b*	3 : 4					
,, ,, ,, ,, ,, ,,	6 : 9					
,, ,, ,, ,, ,, ,,	1 : ..	26 : 27	26·50 : 26·50	±0·50	3·64	0·14
(Cleveland 208*a* x Shepherd 873*b*) F_1 x Shepherd 873*b*	2 : 6					
,, ,, ,, ,, ,, ,,	2 : 5					
,, ,, ,, ,, ,, ,,	4 : 7					
,, ,, ,, ,, ,, ,,	4 : 5					
,, ,, ,, ,, ,, ,,	3 : 6					
,, ,, ,, ,, ,, ,,	6 : 8	21 : 37	29·00 : 29·00	±8·00	3·81	2·10
(Shepherd 873*b* x Federation 346*a*) F_1 x Shepherd 873*b*	.. : 1					
,, ,, ,, ,, ,,	9 : 7					
,, ,, ,, ,, ,,	6 : 6					
,, ,, ,, ,, ,,	4 : 6					
,, ,, ,, ,, ,,	6 : 4	25 : 24	24·50 : 24·50	±0·50	3·50	0·14
Total		72 : 88	80·00 : 80·00	±8·00	6·32	1·27

(*b*) PARENTS OTHER THAN SHEPHERD.

Back-cross.	Observed.		Ratio of 1 : 3	D.	S.E.	D/S.E.
(Shepherd 873*b* x Cadia ,155a) F_1 x Cadia 155*a* ..	.. : 6					
,, ,, ,, ,, ,, ,,	2 : 8					
,, ,, ,, ,, ,, ,,	2 : 3					
,, ,, ,, ,, ,, ,,	2 : 11					
,, ,, ,, ,, ,, ,,	5 : 7					
,, ,, ,, ,, ,, ,,	4 : 8	15 : 43	14·50 : 43·50	±0·50	3·30	0·15
(Cleveland 208*a* x Shepherd 873*b*) F_1 x Cleveland 208*a*	2 : 10					
,, ,, ,, ,, ,,	6 : 6					
,, ,, ,, ,, ,,	2 : 6					
,, ,, ,, ,, ,,	5 : 4					
,, ,, ,, ,, ,,	6 : 4	21 : 30	12·75 : 38·25	±8·75	3·09	2·83
(Shepherd 873*b* x Federation 346*a*) F_1 x Federation 346*a*	4 : 11					
,, ,, ,, ,, ,,	.. : 6					
,, ,, ,, ,, ,,	.. : 3					
,, ,, ,, ,, ,,	2 : 9					
,, ,, ,, ,, ,,	3 : 7					
,, ,, ,, ,, ,,	1 : 7	10 : 43	13·25 : 39·75	±3·25	3·15	1·03
Total		46 : 116	40·50 : 121·50	±5·50	5·48	1·00

Constitution of Varieties.

The varieties used in this investigation can be classified as follows:—

fafa FbFb FcFc.	*FaFa fbfb fcfc.*	*fafa* and either one or both of *fb* and *fc* Recessive.
Shepherd	Cadia Cleveland Federation, and probably Bena Bobin Tuela Turvey Wandilla Yandilla King	Bomen Caliph Canberra Dicklow Jonathan Minister Thew Waratah

Additional data are required in order to be reasonably certain that Bobin, Bena, Tuela, Turvey, Wandilla, and Yandilla King belong to the F_aF_a f_bf_b f_cf_c group. The evidence shows that they have F_aF_a and at least one of f_b or f_c recessive. The F_2 ratios fitting a 27:37 indicate that both f_b and f_c are recessive but it is just possible that some of these ratios are wide deviations from a 9:7.

The F_2 data with Colorado No. 50 fit better a 9:7 than a 27:37 ratio, and therefore Colorado No. 50 is excluded from this classification pending further information.

The actual constitution of the varieties listed in the third column could have been determined by crossing them to F_1 fired plants, but conditions have not permitted this.

5. Acknowledgments.

I am indebted to Miss F. E. Allan for help in certain biometrical aspects of the paper and to Messrs. C. S. Christian, K. Loftus Hills, S. G. Gray, and E. C. Bailey for assistance in field work.

6. Literature Cited.

Fisher, R. A., 1932. Statistical Methods for Research Workers. Text. 4th Edition. (Oliver and Boyd, London.)

Hayes, H. K., and Garber, R. J., 1927. Breeding Crop Plants. Text. 2nd Edition. (McGraw-Hill, New York.)

Pearson, K., 1924. Tables for Statisticians and Biometricians. 2nd Edition. (Cambridge University Press.)

Tingey, D. C., 1933. Inheritance of Dwarfing in Wheat. *J. Agr. Res.*, 46:75-94.

Tippett, L. H. C., 1931. The Methods of Statistics. (William and Norgate, London.)

Warwick, B. L., 1932. Probability Tables for Mendelian Ratios with Small Numbers. Texas Agric. Exp. Sta., Bull. 463: 1-28.

The Heat of Wetting as an Index of Texture in Irrigated Soils.

*By A. L. Tisdall, B.Agr.Sc.**

1. Introduction.

In irrigation and drainage investigations in the Murray Valley, a need has been felt for some rapid and fairly accurate estimate of texture, particularly as it affects soil permeability. In many soil profiles in this area, there is a considerable range of texture from the surface down to a depth of 6 or 7 feet, which is usually the maximum depth covered by studies of permeability. It follows, therefore, that any estimate of texture must have sufficient range to include any sample between a very sandy surface soil and a heavy clay subsoil.

Of the "single-value" soil constants, moisture equivalent and sticky-point have been most widely used in Australia. The former requires rather costly apparatus, and there are several objections to the use of the latter for permeability studies. As the clay content decreases towards zero, the relation between sticky-point and clay percentage is no longer linear (1), and it becomes increasingly difficult to obtain the sticky-point accurately. Again, the sticky-point is unsatisfactory with gypseous subsoils, and in any case the end-point is somewhat qualitative.

A constant which has been receiving an increasing amount of attention in Europe, particularly for drainage studies in Germany, is the heat of wetting, which is simply the amount of heat, expressed in calories per gram, which is evolved when soil is mixed with water. It was thought that an examination of the factors affecting this value might throw some light on the practicability of its use on Murray Valley soils.

Janert (2), using single base clays, showed that heat of wetting is due to partial heat of hydration of the cations in the clay complex, and that, in normal soils with all the main cations present, heat of wetting varies with the proportion of each cation. It was thought that the variation in exchangeable bases in the clay complex of the soil group examined would not be sufficient seriously to affect the value of heat of wetting for comparative purposes; accordingly, the nature of the exchangeable bases was not systematically examined. Subsequent results, which are discussed below, support this contention.

Other possible factors which could affect heat of wetting are:—

(i) the particle size distribution,

(ii) the percentage of calcium carbonate, and

(iii) the percentage of organic matter.

The latter must be included, as Janert (2) found that the heat of wetting for soils rich in organic matter is above that which would be expected for mineral soils. As the amount of organic matter in the soil group under consideration is low, it would be of interest to determine how far such an amount will affect the heat of wetting.

* Commonwealth Research Station, Merbein, Victoria.

2. Experimental.

(i) *Sampling.*

The samples used in this investigation were drawn from the Murray Valley viticultural areas of Victoria and South Australia. They mainly represent the Mallee soil group, which has been described by Prescott and Piper (3), but also include profiles which appear to belong to the group described by Marshall and Hooper (4) as river flat soils. Altogether, 100 soil samples were taken from a number of representative profiles, each sample representing a six-inch depth interval in the profile. Some soil types were sampled completely to six feet; in others, only the parts of the profile which were of immediate interest were examined. The samples were air-dried and lightly ground to pass a 2 mm. sieve, larger particles being classed as gravel. Sub-samples of the fine earth were further ground for various determinations; to pass a 1 mm. sieve for heat of wetting, and a 0.5 mm. sieve for organic carbon.

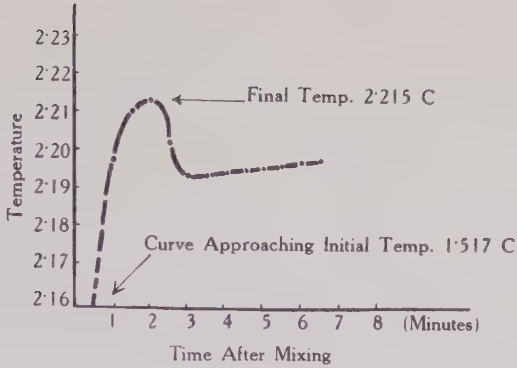
(ii) *Laboratory Determinations.*

Mechanical analyses were carried out on all samples, using the international method with dispersion by ammonia following pre-treatment with hydrochloric acid and hydrogen peroxide. Approximate carbonate percentages were obtained by adding excess .25 N. hydrochloric acid and back-titrating with .25 N. sodium hydroxide.

The method of determination of heat of wetting used was that developed by Janert (7 & 8), which appears to be more rapid and more accurate than that of Anderson (9). The water equivalent of the calorimeter was obtained with sodium thiosulphate. The drying procedure was standardized at 110° C. overnight. A constant temperature room was not available, but the room used was partly underground, and had a maximum diurnal variation of about 3° C. Under these temperature conditions, it was possible to duplicate results to within 5 per cent., which was the maximum variation allowed on any one sample. It was found possible to reduce the time of standing from 1 hour to 15 or 20 minutes. This is necessary with limited apparatus, and is quite permissible, as long as the water in the calorimeter is thoroughly stirred and a series of temperature readings taken at half-minute intervals prior to mixing, to ensure that equilibrium has been reached.

In the majority of samples, the curves followed those given by Janert (8). In the case of gypseous samples, however, the temperature generally reached a maximum about one minute after mixing, and then fell slightly, in contrast to the normal curve, which tended to reach a constant temperature and thereafter rise slowly (Fig. 1).

Soil organic matter was estimated by the wet method of determination of organic carbon described by Walkley and Black (10). This method has been used successfully on Mallee soils by Walkley (11), and has also been found practicable on carbonate soils in the United States of America (12). It gave duplicates to within 5 per cent. of the determination in the majority of cases, but, on samples with the organic carbon in the region of 0.03 per cent., a variation of 10 per cent. between duplicates was allowed. A 75 per cent. recovery factor was assumed throughout, and the organic carbon values were then corrected according to the chlorine content of the sample (Walkley (11)).



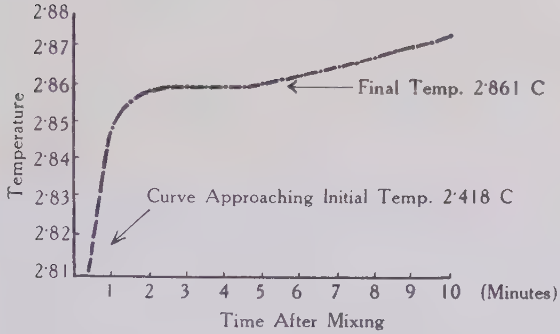


Fig. 1.—Heat of wetting curves. The lower curve is of the type generally obtained; the upper curve was obtained with a sample containing 1·9 per cent. gypsum. The temperatures shown are merely relative Beckmann thermometer readings.

3. Statistictal Examination of the Data.

Assuming a linear relationship between heat of wetting and the factors mentioned above, regression equations were calculated relating heat of wetting to the proportions of silt, clay, calcium carbonate, and organic matter. The range of data used in calculating the regression equations is given in Table 1.

Table 1.—Range of Data used in Calculating Regression Equations.

—	Mean Values.	Range of Values.
Heat of wetting	3·18 cals./gm.	0·94 — 9·52 cals./gm.
Silt	6·8 per cent.	1·1 — 26·5 per cent.
Clay	20·8 ,,	4·0 — 58·4 ,,
Calcium carbonate	14·0 ,,	0·0 — 32·3 ,,
Organic matter	0·177 ,,	·029 — 1·172 ,,

The various regression and correlation coefficients are discussed below.

(i) *Relation between heat of wetting and clay content.*

The simple correlation between heat of wetting and clay content is 0.93. The values of heat of wetting and clay, as graphed in Fig. 2, yield further information on this relation:—

(*a*) The plotted values, with few exceptions, lie within comparatively narrow limits over a range from 4 per cent. to 58 per cent. clay, the samples from any one profile giving an even better linear relation.

(*b*) The presence of gypsum in the sample does not appear to upset the relation, there being only one case where a gypseous sample is seriously out of line.

(*c*) All other plotted values which are out of line represent surface samples, in which the discrepancy is probably due to organic matter. These are discussed later.

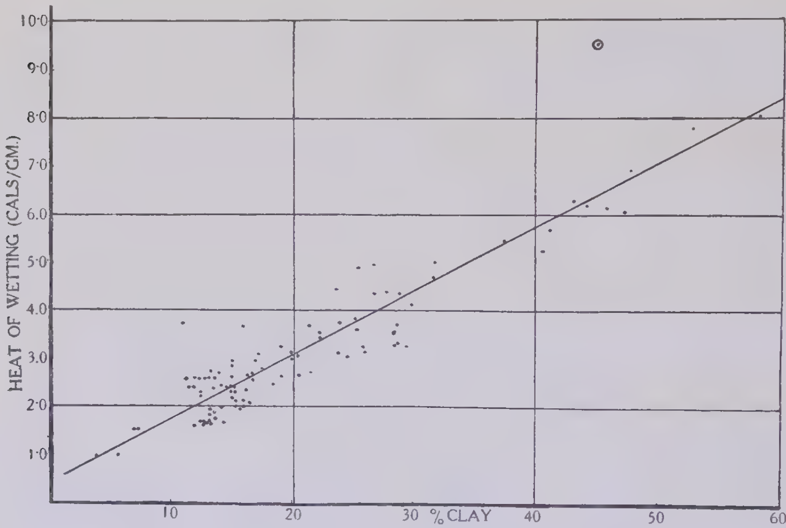


FIG. 2.—Relation between heat of wetting and clay. The point within the circle represents a sample containing 10 per cent. gypsum. All other samples contain less than 4 per cent. The regression line is given by the equation :—

$$\text{Heat of wetting (cals/gm)} = 0{\cdot}3948 + 0{\cdot}13358 \text{ (per cent clay)}.$$

NOTE.—The high heat of wetting value obtained for the sample containing 10 per cent. gypsum may be due to a partial change during oven-drying at 110° C. from $CaSO_4\,{}_2H_2O$, which has a negative heat of solution, to $CaSO_4$, which has a much greater positive heat of solution.

(ii) *Influence of calcium carbonate.*

The multiple correlation of heat of wetting with clay and calcium carbonate is still 0.93. As would be expected, the regression for heat of wetting on clay is significant, and that for calcium carbonate is not. Following Janert's (2) explanation of the origin of heat of wetting,

calcium carbonate would be expected to have no effect on the relation. This is the general experience in the United States of America (Kapp (13)), and is further confirmed by the following correlations:—

(i) Partial correlation of heat of wetting with clay, eliminating calcium carbonate=0.93.

(ii) Simple correlation of heat of wetting with clay:—

(*a*) in soils with less than 2 per cent. calcium carbonate ($n=22$), $r=0.93$,

(*b*) in soils with less than 5 per cent. calcium carbonate ($n=34$), $r=0.91$.

(iii) *Influence of organic matter.*

As has been stated in relation to Fig. 2, most surface samples give a higher heat of wetting than would be predicted from their clay percentage; and this is most probably due to organic matter. Further evidence supporting this supposition is obtained by dividing the samples into two groups:—those from the top 36 inches, and those from depths between 36 inches and 72 inches from the surface. The simple correlations of heat of wetting with clay are significantly different:—

Above 36 inches ($n=.48$) $r=0.89$.
Below 36 inches ($n=52$) $r=0.95$.

(iv) *Influence of silt.*

It has been shown by Kapp (13) that particles of greater diameter than 0.002 mm. exhibit heat of wetting properties. By plotting the average of heat of wetting values quoted by Kapp for each range of particle size, and taking the area of the curve for the "international" silt fraction (0.002 mm. — 0.02 mm.), an average heat of wetting value of 0.9 cals/gm is obtained for silt. The values given by Kapp are not confined to any one soil group, and are therefore too variable to be applied to the soil group under consideration. The contention that the silt fraction exhibits heat of wetting properties, however, is supported by the correlation discussed below.

(5) *General relation.*

The multiple correlation of heat of wetting with clay, silt, and organic carbon is 0.96. All three regression coefficients are individually significant, and enable a significantly closer prediction to be obtained than when using the coefficient for clay alone. The regression equation so obtained is:—

$$\text{Heat of wetting (cals/gm.)}=0.2127+0.1076\ (\%\ \text{clay})+0.0783\ (\%\ \text{silt})+1.0809\ (\%\ \text{organic carbon}).$$

Base exchange may account for much of the residual effect. Although calcium and magnesium are generally the predominant bases in the Mallee soil group (Prescott and Piper (3)), sodium may be sufficiently important to affect heat of wetting values.

4. Conclusions.

From the experiments described, it would appear that heat of wetting may be of considerable value as an estimate of texture in irrigation and drainage studies in the Murray Valley. It is not affected by

calcium carbonate, inappreciably affected by gypsum up to at least 4 per cent., and a satisfactory relationship with clay percentage still holds good with samples as low as 4 per cent. in clay content.

For comparative purposes in any one profile, it is even better than is shown in the general correlations.

In the soils studied, heat of wetting varies mainly with the proportion of clay, but is also augmented by the proportions of silt and organic matter. That this augmentation is slight is due to the low values obtained for silt and organic matter.

5. Acknowledgments.

The author wishes to thank Professor J. A. Prescott, Chief, Division of Soils, for advice and criticism, and Mr. E. A. Cornish, Waite Agricultural Research Institute, for assistance with the statistical treatment.

6. Literature Cited.

1. Prescott, J. A., and Poole, H. G.—*J. Agr. Sci.*, **24**: 1, 1934.
2. Janert, H.—*J. Agr. Sci.*, 24 : 136, 1934.
3. Prescott, J. A., and Piper, C. S.—*Trans. Royal Soc. S. Aust.*, **56**: 118, 1932.
4. Marshall, T. J., & Hooper, P. D.—Coun. Sci. Ind. Res., Bull. 8`.
5. Prescott, J. A., and Piper, C. S.—Coun. Sci. Ind. Res., Pamphlet 8.
6. Piper, C. S., and Poole, H. G.—Coun. Sci. Ind. Res., Pamphlet 13.
7. Janert, H. (1927).—*Landw. Jahrb.*, **66**: 425, 1927.
8. Janert, H.—*Z. f. Pflanzenern., Düng.. U. Bodenk. A.*, **19**: 281, 1931.
9. Anderson, J.—*J. Agr. Res.*, **28** : 1924.
10. Walkley, A., and Black, I. A.—*Soil Sci.*, **37**: 29, 1934.
11. Walkley, A.—*J. Agr. Sci.*, **25**: 598, 1935.
12. Baker, G. O.—*Soil Sci.*, **41**: 1936.
13. Kapp, L. C.—*Soil Sci*, **29**: 401, 1930.

Free-Water Investigations in the South Australian Areas of the Murray Valley.

*By A. L. Tisdall, B.Agr.Sc.**

Free water investigations are being carried out in the principal River Murray irrigation areas in South Australia under the control of the Irrigation Investigation Committee which is a body that has been constituted by the South Australian Department of Lands. The personnel of the Committee is as follows:—W. J. Colebatch, Esq., Deputy Director, Department of Lands, A. G. Strickland, Esq., Chief Horticultural Instructor, South Australian Department of Agriculture, and A. V. Lyon, Esq., Council for Scientific and Industrial Research, (Mr. Geo. Quinn was a member of the Committee prior to his retirement from the South Australian Department of Agriculture.)

Mr. A. V. Lyon, of the Council's Commonwealth Research Station, Merbein, directed the investigations on sites selected by the Council's Division of Soils with due regard to soil type. The co-operation of district officers of the Departments of Lands and of Agriculture of South Australia has enabled the investigating officer, Mr. A. L. Tisdall, to examine the conditions over extensive areas. A report by Mr. Tisdall appears below.—Ed.

1. Introduction.

The problem of unduly high water tables is one that has arisen sooner or later in most irrigation settlements throughout the world, as irrigation practice generally entails excess, rather than insufficient, irrigation water. Perhaps this is natural, as the effects of insufficient irrigation are evident immediately by affecting the current year's production, whereas excesses are reflected more slowly by soil wastage in later years.

The problem is a serious one, as free sub-soil water frequently renders land wholly or partially unproductive. Especially is this so in the Murray Valley, where, associated with free-water movements, there is generally a decided migration of soluble salts in an upward direction. Thus there are two effects on plant life, associated with free water, namely:—

(i) a direct effect on the aeration of the root system, and

(ii) plant injury from excess soluble salts, even though the water table be below the root zone.

The latter effect is the more important and must be regarded as permanent, since reclamation of so-called "salty" land is usually a matter of extreme difficulty under Murray Valley conditions.

Investigations of the problem in the South Australian portion of the Murray Valley during the period 1933-1936 have followed three main lines—

(i) an examination of existing free-water conditions;

(ii) the relation of free water to irrigation; and

(iii) the relation of free water to agricultural drainage.

An account of the work carried out along these lines is given below.

* Commonwealth Research Station, Merbein, Victoria.

2. Examination of Existing Free-Water Conditions.

(*a*) *Procedure.*

The method used was to examine free-water levels at a number of points in long-distance sections embracing various soil types, the objects being:—

(i) to determine the existing levels and extent of free water; and

(ii) to observe fluctuations in level throughout the irrigation season.

In the Berri area, three such lines of 12-foot test wells were put down in 1933, and in the Barmera area two. In 1935, four lines were put down in Renmark, and these are discussed later. The test wells used are simply 2-in. down-piping, perforated at 4-in. intervals and closed at the bottom. The wells have a loose lid and are sunk 11 feet into the ground. Surface contours were obtained in a preliminary survey, and, on sinking the wells, free water was found comparatively near the surface over considerable areas. The levels have been read monthly throughout the winter months, and weekly throughout the irrigation seasons; the results have been graphed in relation to contour and the incidence of irrigation. The ideal readings would be just before, and at intervals after, each irrigation, but, in an irrigation district on a roster system, such a procedure is hardly practicable. The weekly readings give almost the same information and are easily obtained.

In addition, a survey of the horticultural plants in the vicinity of the wells has been made annually, to ascertain their reaction to various free-water conditions.

(*b*) *Results.*

In most cases, levels rise markedly, and in some cases 7 or 8 feet, after each irrigation. In many cases, also, rises in level precede the actual irrigation of the soil in the vicinity of the well. By sinking extra test wells in appropriate places, and by manipulating the dates of irrigation of adjacent holdings, it was possible to show that subterranean water movements from adjacent irrigated land were responsible for such rises in the water table.

In general, the conclusions to be drawn from these studies and for the particular soils involved, are:—

(i) Free sub-soil water is present in the majority of soils in these areas throughout the year;

(ii) in some cases, irrigation of one holding may influence the water table level on adjacent holdings;

(iii) present district practice is responsible for the maintenance of a free-water level within 11 feet of the surface, in most parts of the areas concerned;

(iv) there is a definite relation between water level and the condition of surface soil and plant and where the level is maintained near the surface throughout the year, in nearly all cases the soil appears salty and the plants do not thrive;

(v) there appears to be no direct relation between soil type and incidence of free water (Fig. 1).

The water table tends to reach a basal level during the winter months, and fluctuates above this level in the summer months, generally rising sharply after each irrigation (Fig. 2). Immediately after an irrigation, the table temporarily rises, but rapidly loses part of this rise in a few days; thereafter it drops much more steadily until the advent of the next irrigation or of equilibrium during the winter period (Fig. 2).

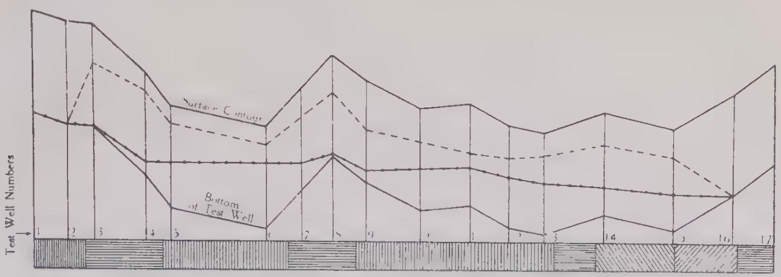
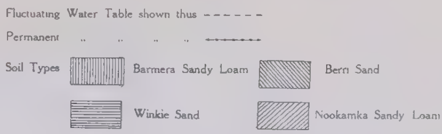


FIG. 1.—Average free water levels in relation to soil type. Section D Barmera. Scales: Vert. 1″ = 20′; hor. 1″ = 20 chains.



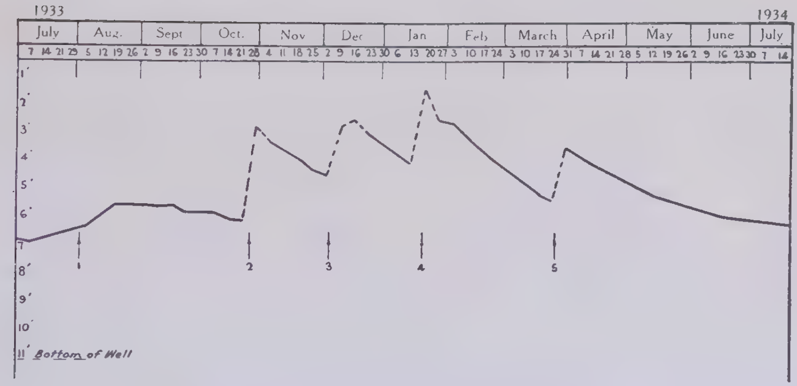


FIG. 2.—Wa er table fluctuations over Irrigation Season 1933-34.
Well No. 1. Section C Berri.
Dates of Irrigation shown thus ↑
Water level thus ———
Temporary unstable level thus — — —

3. Extension to Renmark Areas.

The method of using test well lines to obtain information on the extent of the problem in an area has been extended to the Renmark districts. Several lines were established in Renmark, Block E, and Chaffey areas in 1935, with this object. These lines, however, have an additional aim, and that is to give information, if possible, on the influence of the river and Ral Ral Creek levels on the height of the water table in various parts of the settlements. Here again, surface contours

have been obtained. In addition, the South Australian Department of Lands have records, for the last five years, from a number of observation holes in various parts of the Renmark areas. The observations so far obtained indicate that for these particular Renmark soils:—

(i) the water table can be continuously followed right to the creek or river (Fig. 3);

(ii) water levels on irrigated country rise with irrigation. (The fluctuations are similar to those shown in Fig. 2.)

(iii) general water levels have been steadily rising for the last five years;

(iv) as a rule, the table is higher in irrigated country than in the surrounding un-irrigated land, even though the latter is on a lower contour.

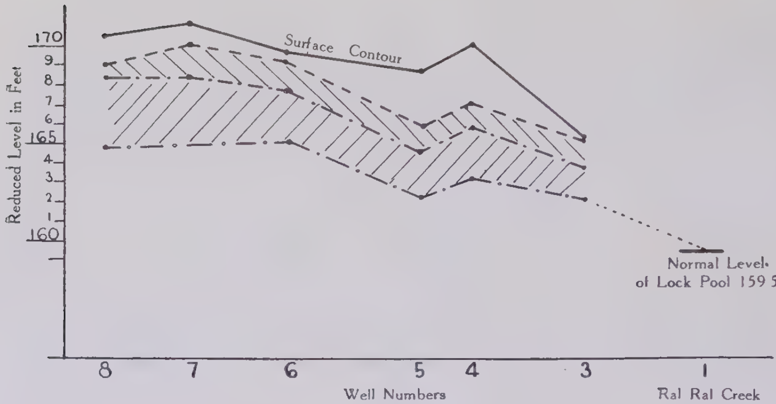


Fig. 3.—Free water fluctuations (interim results). Block E Renmark. Sec. B.
// = Free water fluctuations, August, 1935, to April, 1936.
\\ = Temporary rise due to 5 inches rain, January, 1936.
Horizontal Scale, 1″ = 50 chains.

4. The Relation of Free Water to Irrigation.

(a) Plot Lay-out and Procedure.

With a view to determining the effect, on both plant and water table, of using smaller amounts of water than is the usual practice, plots have been laid down in various centres along the river—at Renmark, Berri, Barmera, (both Nookamka and Loveday), Waikerie, and Pyap. It was established by Barnard (1) that the root zone of the sultana vine is comparatively shallow in the river soils. That this is the case with all the important vine varieties grown along the river has been borne out by observations on many different soil types. The majority of vine roots are within 2 feet of the surface, and on some soil types much shallower.

Fruit trees also, with few exceptions, appear to be comparatively shallow-rooted. The aim in irrigation, then, is to moisten the soil to the depth of these roots and to prevent further penetration as much as possible.

It was recognized that the best method of application of water, and the amount applied, would vary with the soil type; accordingly, where possible, each site is on a different soil type, with an environment that

permits rapid irrigation. Nine such plots, in the above-mentioned districts, have been laid down. The soil-types examined include:—

(i) Bookmark sandy loam (two plots).
(ii) Berri sand.
(iii) Winkie sand.
(iv) Barmera sandy loam.
(v) Berri sandy loam.
(vi) Loveday sandy loam.
(vii) Unclassified at Waikerie and Pyap (two plots).

The above soil types were named and described by the Division of Soils (2), but the Waikerie and Pyap soils have not yet been defined. The Pyap soil is a light sand, probably similar to Winkie sand, the Waikerie soil being slightly heavier in texture. Test wells were installed at the top and the bottom of the irrigation run, on each plot. As opportunity offered, more soil types were included, if possible in different districts, in order to demonstrate methods of irrigation to growers. An additional site was chosen in Mypolonga in 1935.

A system of multi-furrow irrigation was adopted on all sites, because this system seemed to suit the conditions best. Sprinkler irrigation, either surface or overhead, is probably superior, but it is comparatively expensive. Moreover, all these settlements, except the Loveday section of Barmera, are laid out with channel systems, both for supply and distribution with the holdings, and the cost of a change-over would be considerable. Flood irrigation need not be considered, except for soils with relatively little grade, as the majority of the soils scour too readily.

Actually, the system adopted, that of multi-furrow irrigation, is a modified flood system, in that as many furrows per row as possible are used, in order to apply the water quickly and evenly. Modifications are necessary on practically every holding, but obviously they must be left to the individual. Change of the furrow position in a row is sometimes beneficial in preventing high concentration of the salts parallel to the irrigation furrow.

"Initial" and "soakage" rates of flow were used on all plots. This simply means that the flow of water is so arranged that a large stream reaches the end of the furrow as rapidly as possible. The rate of flow can then be cut down so that the stream continues at the end of the furrow, with as little over-run as is consistent with adequate irrigation of the end portion of the furrow. In this way, the excess irrigation of the head ditch end of the row, which is obviously a natural defect of furrow irrigation, is reduced to a minimum.

In the preliminary single-furrow investigations various periods of application and rates of flow were tried, and the effect on the soil examined in the following three ways:—

(i) Free-water levels were examined before and after irrigation, both in test wells and in supplementary auger holes sunk at various points.
(ii) Moisture contents at various depths were determined.
(iii) "Penetration" or "percolation" profiles, 24 hours after irrigation, were examined. (Such profiles are obtained by digging a trench across the furrow and graphing the lateral and vertical penetration of the irrigation water.)

As the work proceeded, and information was secured from preliminary single-furrow investigations, the area under observation was increased from one or two rows, to the full size of the observation plot, generally 1 or 2 acres.

(*b*) *Results.*

A few typical penetration profiles are illustrated in Figs. 4, 5, 6, and 7. Fig. 4 shows three profiles at various points along a furrow, namely, near the headland, half-way along the furrow, and near the footland. These profiles illustrate the much greater penetration of irrigation water obtained near the head-ditch in a "sand" soil-type. Similar profiles in Fig. 5 show the temporary delay in penetration where a "soft limestone" horizon exists at a depth of about 2 feet. This type of penetration often occurs in the sandy loam soil types in the areas under examination. Figs. 6 and 7 show typical multi-furrow profiles for the two types of penetration. In the "sand" types, once the penetration from adjoining furrows links up, downward penetration is very rapid (Fig. 6). Where the soft limestone horizon is present, as in Fig. 7, downward penetration is delayed for a time.

The duration of irrigation on all sites was reduced far below district practice; and the plants continue to thrive, in some cases improving over the period of the experiments.

The usual methods of measurement of water applied to plots was to collect the water delivered per furrow in a vessel of known capacity, but in addition, on the two Berri sites (Berri sand and Winkie sand), modified Dethridge wheels were installed. The number of sites on which these wheels can be used is limited, as they require a difference in level, above and below, of at least 4 inches.

In general, the plots were irrigated adequately with less than 4 inches of water over each plot, as disclosed by both methods of measurement, this amount being well below the district average.

Perhaps the most important disclosure, however, was the more even distribution of water over the area, and consequent reduced additions to the water table below the root zone. On most of the sites, the irrigation water generally linked up with the water table, but it was found possible to limit the excess so that the level did not arise appreciably.

The results of these plots indicate that, on runs of up to 6 or 7 chains, the soils on the sites examined can be adequately irrigated in six hours, or less, per furrow. In at least part of the irrigation season, all sites can be watered in less time, and the average time of application would be nearer four hours per furrow. This, of course, does not apply to longer runs; on the "sand" types, 7 chains may be considered too long, the optimum length being about 4 chains.

Efforts to increase efficiency of irrigation, then, have been along the following lines:—

(i) An increase in the number of furrows per row, which involves increase in the number of outlets in the head ditch.

(ii) A reduction in the time of irrigation.

(iii) The introduction of "initial" and "soakage" rates of flow in a furrow, in contrast to the usual practice of a small constant stream throughout.

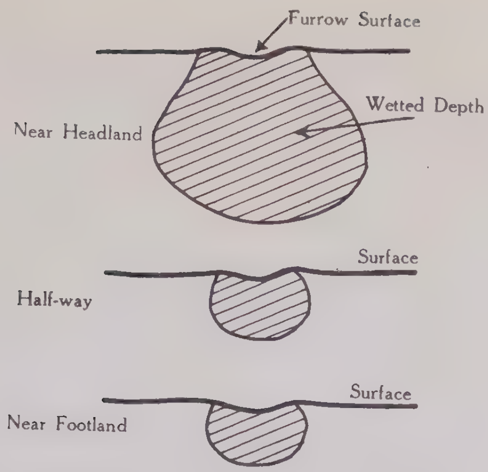


FIG. 4.—Percolation profiles with very light irrigation on a "sand" type. Scale ½″ = 2′

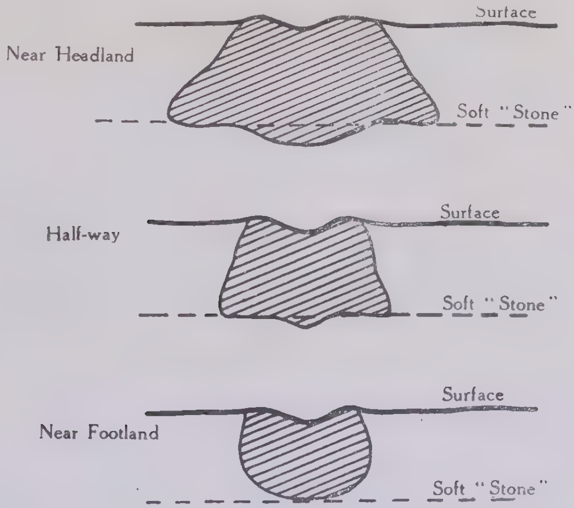


FIG. 5.—Percolation profiles showing delayed penetration from a single furrow. Scale ½″ = 2′.

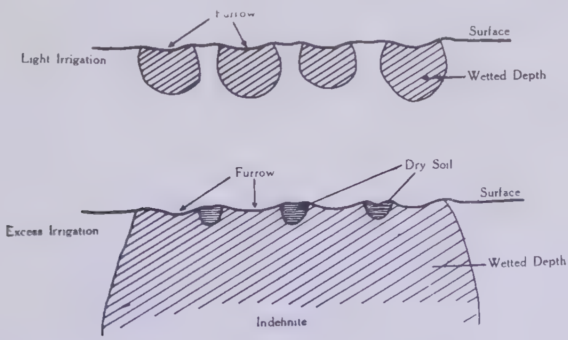


FIG. 6.—Percolation profiles of multi-furrow irrigation in a "sand" type. Scale ½″ = 3′.

(c) General Application.

The methods outlined have other beneficial effects when applied to community settlements. All the irrigation settlements in the areas under discussion use water pumped from the Murray, and consequently the organization of an irrigation is governed by the capacity of the pumps. This necessitates the holdings being watered in rotation on a fairly rigid roster system.

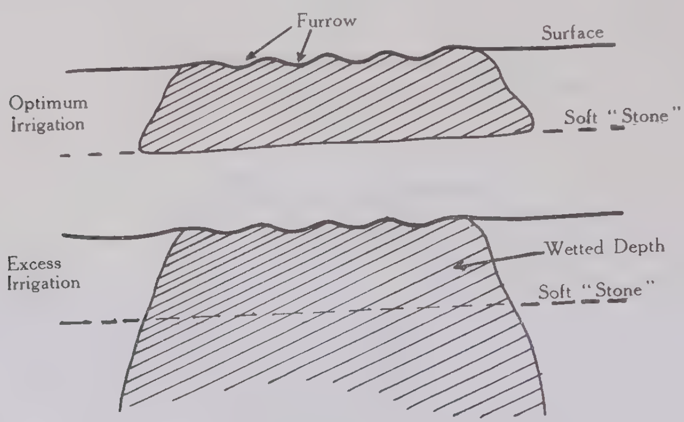


FIG. 7.—Percolation profiles of multi-furrow irrigation showing delayed penetration. Scale $\frac{1}{2}'' = 2'$.

It will be evident that quicker applications of water on any one holding will enable the irrigation of a settlement to be completed in a shorter time. Consequently, it is possible to have the irrigations closer together, which increases the margin of safety in hot weather. Again, as the pumps are worked as near as possible at full capacity, the shorter the irrigation period, the lower the cost of pumping per irrigation.

5. The Relation of Free Water to Drainage.

(a) Description.

In South Australia, drainage on any community basis, such as is being carried out in the Mildura districts, has so far not come into practice, although one scheme is under construction at Barmera. Perhaps the most striking development in drainage in South Australia in recent years has been the success of shaft-and-bore drainage at Waikerie.

In quite a number of cases in that area, below the soil horizons there are strata of stone of varying hardness and varying thickness, and extending variously from a depth of approximately 5 feet to 20 feet or more.

In these cases, it is the stone which bears most of the free water, and the drains, which are generally laid on, or near the surface of, this stone (i.e., at about 5 feet,) have water below them. The outfall for drainage systems in the area has been into shafts, originally put down to 6 or 8 feet, and further equipped with a 4-inch mining bore penetrating to about 100 feet. The casing of the bore extends about 2 feet up into the shaft, and thus acts as a silt trap. The bores being watertight, only water above the 6-ft. level could be removed. Recently,

however, in a number of cases the depth of the shafts has been increased to 20 feet, by blasting and "gadding" the stone. It has now been found that the tile drains feeding the shaft have ceased to run, as the shaft drains the strata from below the depth of tile drainage.

(b) Procedure.

Test well lines have been put down in various directions, both radiating from single deepened shafts and linking up two such shafts. Records have been taken over several years, and the range of effectiveness of this type of direct drainage has been examined, the records being graphed in relation to surface contour of the well-sites. Soil profiles in both shafts and test well holes were examined wherever possible.

(c) Results.

It was found that with shallow shafts, say 6 or 8 feet, the surrounding water table tends to follow surface contour (Fig. 8). With the

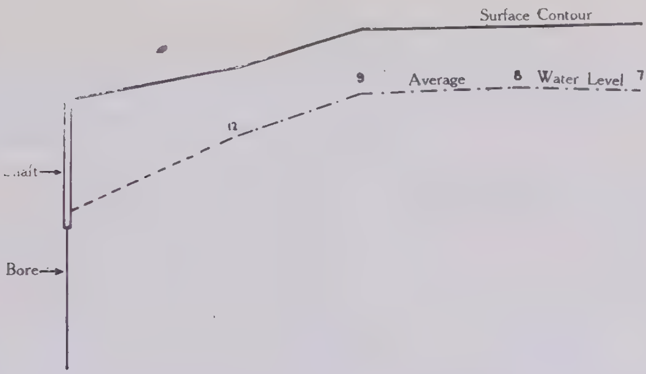


Fig. 8.—Free water levels in the vicinity of a shallow shaft at Waikerie. The water level tends to follow surface contour. Scales: Hor. 1″ = 3 chains, vert. 1″ = 12′.

20-ft. shafts, however, there is a definite water level slope to the shaft, the demonstrable sphere of influence being at least 4 chains (Fig. 9). Fig. 10 shows the gradient in a sandy soil with a steep surface contour. It is thought that the range of influence may sometimes be considerably greater, as drains 6 and 8 chains away have stopped running after a bore has been in operation for some time. However, the effectiveness of the bores varies considerably. This is readily understandable when the very heterogeneous nature of the strata is considered. Stone is rarely encountered above 4 to 5 feet, but below that depth there are three possible profiles down to the depth of the shaft (generally about 20 feet):—(1) no stone present, (ii) stone present to the full depth, and (iii) stone strata, generally 1 to 3 feet in thickness, interspersed with horizons of sandy or clayey material. Similar variations are encountered when sinking the 4-in. bore, although it is usual to strike stone at some depth in the bore.

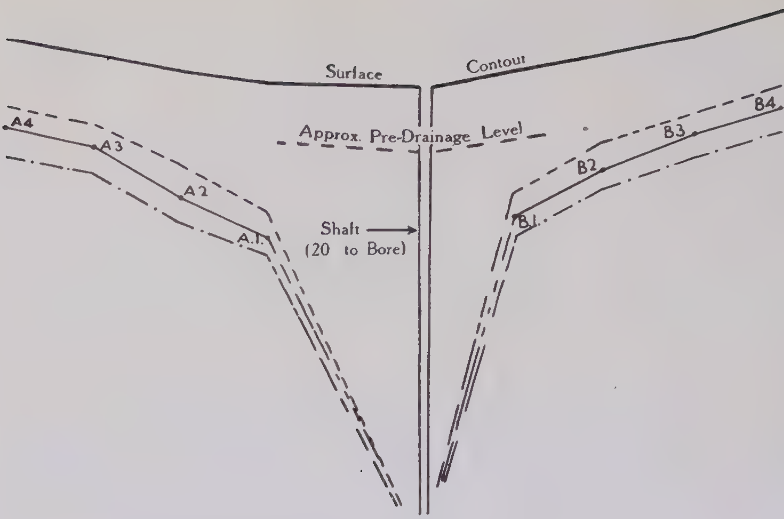


FIG. 9.—Free water levels in the vicinity of a deep shaft at Waikerie.
Usual upper limit of free water, thus — — —
Usual basal level of free water, thus — · — · —
Average level of free water, thus ————

Scales: Vert. 1″ = 9·25′; hor. 1″ = 2·3 chains

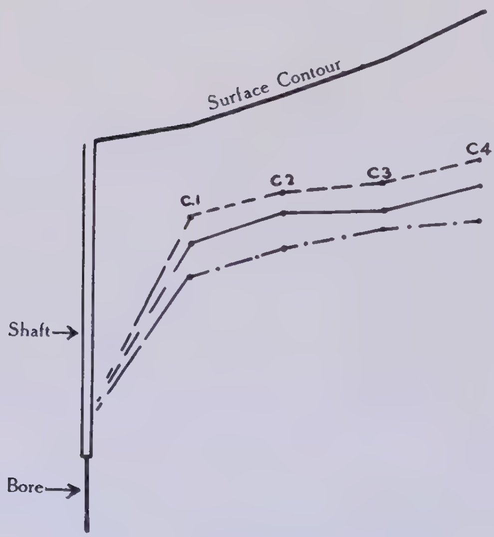


FIG. 10.—Same as Fig. 9, but with a much steeper surface contour.
Scales: Vert. 1″ = 8′;
hor. 1″ = 2 chains.

These variations explain why the effect of a bore on the water-table is so difficult to demonstrate with test wells, but, from fairly complete observations, it would appear that the usual radius drained efficiently by a bore is about 6 chains, the water table being lowered to a safe depth below the root zone.

6. Cover Crops.

A practice of value in control of free water, and which should be mentioned here, is that of sowing cover crops. Tick beans and other leguminous crops are useful in this respect, and, where the land is too salty for legumes to do well, barley will often grow. On some sandy slopes, difficulty is experienced in getting a satisfactory stand of leguminous cover crops, and here again, barley and wheat are often used. The crops are ploughed in early, if possible, before the vines sprout, so that they shall not compete with the horticultural plants.

As has been shown by West (3), and confirmed on lighter soils at Merbein, tick beans are very shallow-rooted, about 70 per cent. of roots being within 8 inches of the surface; they thus have the effect of keeping the surface soil dry. Consequently, in a wet winter, rain water which would ordinarily raise the water-table appreciably (rises of up to 2 feet have been observed) is held in the surface soil.

Interplantings with lucerne have been used with success on the heavier soils of the Murrumbidgee irrigation area, but with lighter soils there are obvious difficulties, namely:—

(i) Rapid irrigation becomes impossible, as furrows become ineffecitve. The multi-furrow system being used demands clean cultivation.

(ii) The lucerne is using most moisture when the requirements of the horticultural plants are greatest. This is not so serious in heavy soils; but in lighter soils, with which we are chiefly concerned, surface drying-out in summer is almost as great a problem as free water.

Lucerne is, however, useful on the footland, i.e., at the end of the irrigation run, to use up any surplus water from furrow irrigation. It is important that this lucerne be looked on primarily as a drying-out agent, rather than a source of fodder. By this is meant that it should not be designedly watered as a crop, but should merely be present to absorb the over-run.

7. Conclusion.

In conclusion, it may be stated that investigations in South Australia have been concentrated mainly on the prevention of the accumulation of free water by more efficient irrigation. In addition, in the Waikerie settlement, the possibilities of shaft drainage have been investigated, the general impression being that in many cases in limestone country the shaft-and-bore system is more efficient than tile drainage.

Efficient drainage is not always possible and is always costly. Further, the practice of leaching salt out of surface soil with heavy applications of irrigation water should be undertaken only where satisfactory subsoil drainage exists.

8. Acknowledgments.

Thanks are due to Mr. A. C. Ingerson, of Berri, a part-time officer of the Council for Scientific and Industrial Research, for assistance in initiating the work and in continuing the necessary observations, and to officers of the Departments of Lands and of Agriculture in South Australia for their co-operation throughout the investigations.

9. Literature Cited.

1. C. Barnard.—The root system of the sultana. This *Journal*, **5**: 88, 1932.
2. T. J. Marshall and P. D. Hooper.—A soil survey of Berri, Cobdogla, Kingston, and Moorook Irrigation Area, and of the Lyrup Village District, South Australia. Coun. Sci. Ind. Res., Bull. 86.
3. E. S. West.—The root distribution of some agricultural plants. This *Journal*, **7**: 87, 1934.

A Note on the Effect of Sulphuring the Sultana Vine.

*By J. E. Thomas, B.Sc., B.Agr.Sc., B.V.Sc.**

Several viticultural writers† suggest that the practice of applying sulphur dust to the vine has advantages additional to its action as a specific for the control of powdery mildew. It is stated that an application at flowering time results in a better set of fruit, more particularly so in the case of varieties such as the Muscat of Alexandria, which is often subject to "coulure" or faulty setting. It has also been claimed that this practice, when carried out consistently through the season, hastens maturation of the fruit. It was decided to investigate the matter.

An area of vines in which oidium had been known to occur for some years was selected for experiment. At flowering time, on 8th November, 1932, twenty random blocks were marked out along a line perpendicular to the direction of a slight breeze then prevailing. Each block consisted of two vines—control and sulphured. By means of a blower, the sulphur dust was then applied to the latter vines. No further applications were made that season. At harvest time, a small amount of oidium was noted. The yields of the fresh fruit from each vine were recorded, and, in addition, a composite sample, selected from at least twenty bunches, was taken from each vine. The juice was then expressed and a specific gravity determination made with a Baumé spindle. This can be used as an index to maturation. The results are shown in Table 1:—

TABLE 1.

Treatment.	Mean Yield of Fresh Fruit.	Mean Specific Gravity of Juice.
Control	60·9 lb.	11·00° Baumé
Sulphured	70·0 lb. (P = ·05)	11·00° Baumé

The application of sulphur significantly increased yield without influencing the specific gravity of the juice.

Bioletti has suggested (*loc. cit.*) that the mechanical effect of sulphur dust may favorably influence setting. In order to determine whether the increase in yield obtained above could be attributed to oidium control or to a better setting of the fruit as suggested above, an experiment was carried out in the following season. In this case,

* Commonwealth Research Station, Merbein, Victoria.

† Perold, A. I. "Treatise on Viticulture" (McMillan and Co., 1927, p. 459).
Bioletti, F. T. "Oidium of the Vine." Cal. Agr. Exptl. Stn. Bull., No. 186 (1907).
Castella, F. de, and Brittlebank, C. C. "Oidium of the Vine." Vic. Dept. of Agric., Bull. No. 50 (1924).

there were 24 replications of three treatments:—(*a*) control, (*b*) sulphured, and (*c*) dusted with kaolin—a fine powder of no fungicidal properties. The dusts were applied at flowering time—6th November, 1933. In order, if possible, to eliminate oidium as a complicating factor, two additional sulphurings were given to all the vines—the first 10 days, and the second 28 days later. A careful examination failed to disclose any indication of oidium either during the season or at harvest. The results are shown in Table 2:—

TABLE 2.

Treatment.	Mean Yield of Fresh Fruit.	Mean Specific Gravity of Juice.
Control	54·0 lb.	10·55° Baumé
Sulphur-dusted	54·0 lb.	10·55° Baumé
Kaolin-dusted	54·5 lb. (P > ·05)	10·80° Baumé (P > ·05)

Neither of the results of the two treatments differed significantly from the control.

The effects of regular applications were studied in the next season. The two treatments—control and sulphured—were arranged on Student's *abba* system with 33 replications of each treatment. The sulphur was applied in the form of a suspension of colloidal sulphur at the rate of 4 lb. per 100 gallons on the following dates:—11th and 17th October, 7th November, 5th and 19th December, 1934, and 12th January, 1935. The vines were harvested on 26th February, on which date every difference in maturation should be reflected in dry weight. In this season also, a careful search disclosed no evidence of oidium infection. At harvest time, specific gravity determinations were not made; instead, after the individual yields of fresh fruit were secured, the whole of the fruit from each treatment was put together, dried, and weighed. The results are shown in Table 3:—

TABLE 3.

Treatment.	Mean Yield of Fresh Fruit.	Mean Yield of Dried Fruit.
Control	49·3 lb.	13·4 lb.
Sulphured	44·7 lb. (P > ·05)	13·1 lb.

No significant difference in fresh fruit yields was obtained, and the difference in dried weights was smaller still. In the absence of oidium, regular sulphuring does not appear to influence yield.

The general result of the three experiments would therefore indicate that any increase in yield as the result of sulphuring can be attributed to its specific action in controlling oidium.

A Note on the Treatment of Hail-Damaged Sultana Vines.

By *J. E. Thomas, B.Sc., B.Agr.Sc., B.V.Sc.**

As a result of a severe hailstorm on 24th October, 1934, considerable damage was caused to a large area of sultana vines in the Mildura district. On the affected area, from 50 to 95 per cent. of the crop was lost, the shoots were badly injured, and there was considerable defoliation. It was then considered advisable to determine if any advantage would result from re-pruning. This consisted of cutting back the injured shoots in the pruning area to two buds, in the hope of stimulating the growth of strong laterals which would then serve as pruning wood during the next season.

Experimental Results.

Within a week after the storm, a row of vines was selected, and in it were set out random blocks with 25 replications of the following treatments:—(*a*) control, and (*b*) re-pruned. Only from eight to ten shoots in the pruning area were thus treated, and the loss of bunches was negligible. The primary crop was not recorded, but was approximately 7 lb. of fresh fruit per vine. Normally, it is not worth while to harvest the second crop, i.e., those bunches which develop late in the season from laterals arising from the distal end of the growing shoot. In this instance, however, it was of considerable value and was harvested on 22nd March. An examination of five samples of the expressed juice gave the following mean values:—Specific gravity 13.6° Baumé, and acidity as tartaric acid 7.2 gms. per liter. The specific gravity compares to advantage with that found in the mature primary crop, but the acid content is approximately double.

At the next pruning, in June, 1935, a record was taken of the percentage of canes broken when securing them to the trellis wires. To eliminate any possible personal bias, this work was carried out by an operator not conversant with the experiment. The yield records at the subsequent (1936) harvest are given in Table I.:—

TABLE I.

Treatment.	Yield 1934-35.		Weight of Prunings.	Broken Canes.	Number of Bunches.	Yield 1935–36.	
	Fresh.	Dry.				Fresh.	Dry.
	lb.	lb.	lb.	%		lb.	lb.
Control ..	6·72	1·93	8·86	18·9	31·3	52·6	11·81
Treated ..	7·06	1·83	9·48	12·5	32·3	59·6	13·32
	(P > ·05)		(P > ·05)	(i)	(P > ·05)	(P > ·05)	

(i) Value of P just greater than ·05.

Unfortunately, the high variation rendered the detection of small significant differences impossible. None was significant, with the

* Commonwealth Research Station, Merbein, Victoria.

possible exception of the percentage of broken canes. In practice, however, greater fragility of the untreated canes is not of any great importance. One or more additional canes can be selected at pruning time in order to compensate for any that may be broken when later securing them to the trellis wires.

In considering the response of the sultana to this treatment, it has to be remembered that, in this variety, the accessory buds are almost invariably barren. After destruction of the bunches, the only prospect of obtaining a first crop lies in the development of the main dormant buds. Late in the season, the chances of these developing are extremely remote. Re-pruning, therefore, cannot be expected to improve the primary crop to any extent, and its value, if any, would lie in securing better pruning wood. It should be of such a nature that it does not affect the remnants of the first crop or interfere with the development of the second. Hence, it should be limited to the shoots on which pruning wood is to be selected.

Lyon* found that re-pruning after a severe early frost on 25th September, 1927, was of no advantage. Dupay† concluded that it is only of value when the season is not too far advanced. He considered that it is of some value in securing better pruning wood. Winkler‡, who carried out a series of experiments on vines frosted in varying degrees, opportunely points out that the response is intimately associated with the fertility of the accessory buds and hence differs according to the variety. An examination of his results with the sultana would indicate that, in cases where the extent of the injury is comparable with the hail damage recorded in this paper, re-pruning is not necessary. Our experiment suggests that the extra labour of re-pruning is not warranted, and, on general grounds, it would appear very problematical whether it would be worth while under any conditions.

---

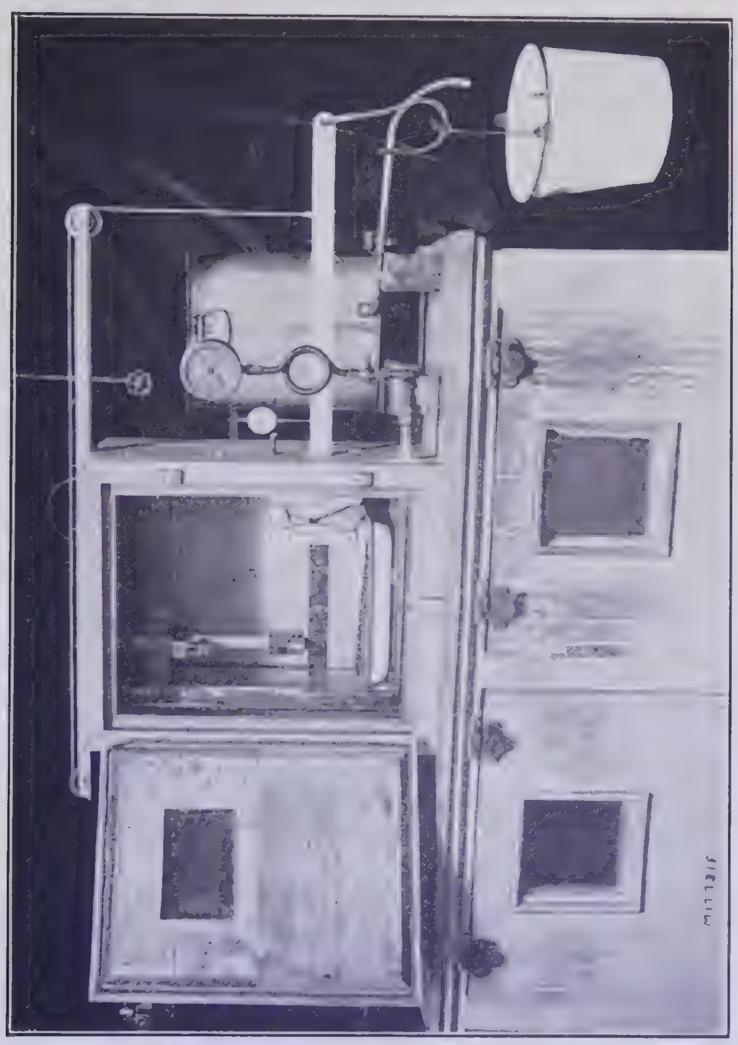
* Lyon, A. V. Unpublished data.

† Dupay, A. "Repruning After Hail" (Translation title). Prog. Agric. Vitic., 103, 441-3 Abstracted in *Horticultural Abstracts* 5 : 76, 1935.

‡ Winkler, A. J. "Treatment of Frosted Grape Vines". *Proc. Amer. Soc. Hort. Science*, 30 : 253, 1933.

PLATE 1.

(Strength Tests Perpendicular to the Grain of Timber at Various Temperatures and Moisture Contents. See page 265.)



Apparatus for Tests.

PLATE 4.

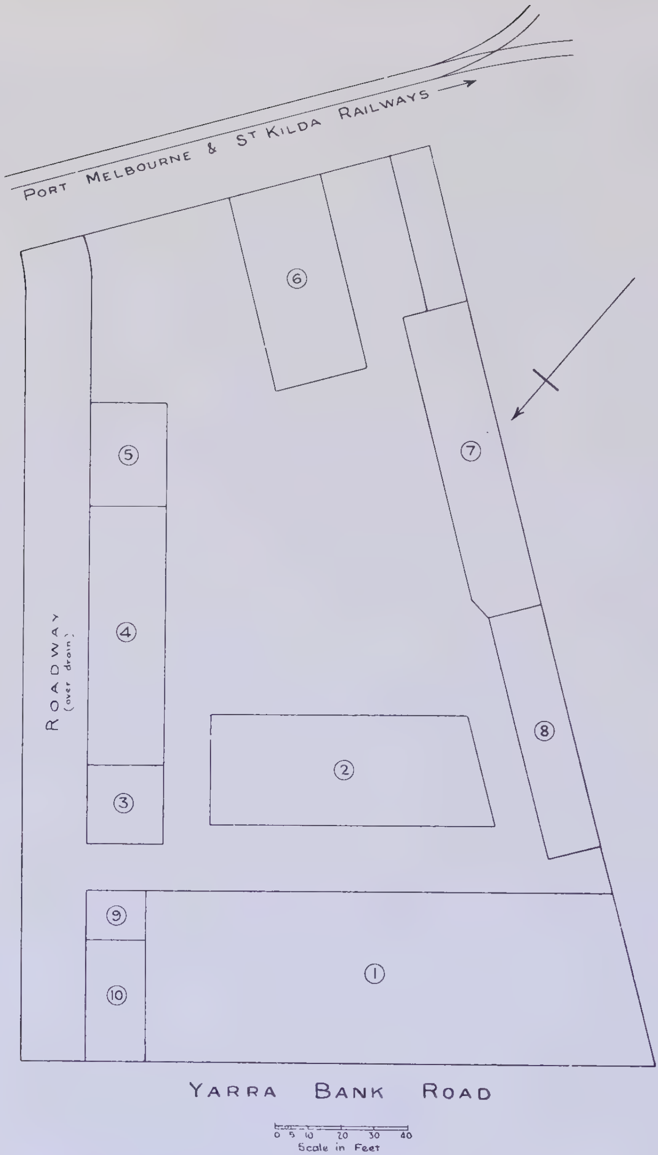
("Firing"—A Heritable Character of Wheat. See page 283.)

Part of a segregating row in an F_3 showing two "fired" plants in the centre and normal plants on either side.

PLATE 5.

Front View of Laboratory for Division of Forest Products, Yarra Bank Road, South Melbourne.

PLATE 6.



Layout of Site for Division of Forest Products, Yarra Bank Road, South Melbourne.

1. Main Laboratory Building.
2. Timber Mechanics Laboratory.
3. Boiler Room.
4. Seasoning Laboratory and Offices.
5. Preservation and Gluing Laboratory.
6. Sawmill.
7. Woodworking Shops.
8. Engineering Shops.
9. Switch Room.
10. Garage.

NOTES.

The New Laboratories of the Division of Forest Products.

In a previous note (this *Journal* 8: 323, 1935), mention was made of the erection of new laboratories for the Division of Forest Products rendered possible by the Commonwealth Government's allocation of £25,000 from unemployment funds.

It was also mentioned that the necessary land was being made available by the Government of Victoria for a nominal rental.

The laboratories, which are located on the bank of the River Yarra on the south side of Yarra Bank-road, South Melbourne, and a stone's throw from the southern end of the Spencer-street Bridge, are now practically complete; it is expected that the Division will be installed in its new quarters by Christmas time or shortly after. A photograph and layout of the laboratories are given in Plates 5 and 6 opposite.

The site is approximately 1 acre in extent, including on the eastern boundary, a drain which is being covered to form a roadway the full depth of the block. With the exception of this roadway, the whole of the north side or the frontage is occupied by the main building. This is of steel frame construction with a brick shell, and is 175 feet long by 52 feet deep. It is three storied except for the eastern end, where there are two stories—a garage at the ground level, and a caretaker's cottage above. The building is such that a fourth story can be added when necessary.

Owing to the poor nature of the foundation, the building is carried on some 240 piles, averaging 45 feet in length, and driven in groups under the main supporting columns of the steel frame. The pile heads are capped in concrete and joined with reinforced concrete beams over which is laid a heavy reinforced concrete raft, which also forms the floor at the ground level. The eastern portion of the building, at this level has been fitted to store the authenticated wood collection which is now extensive, while the western end provides space for constant humidity boxes, etc., and for the storage of experimental timber before or after test.

The first floor is reached from the main entrance in the centre of the frontage by a flight of stairs leading to a lobby attractively flush-face panelled in Queensland walnut and silver ash, and floored with tallowwood parquetry. The eastern end comprises inquiry office and telephone room, offices, fireproof and publications stores, and a large library and lecture hall, 50 feet x 30 feet, with mountain ash fittings and a polished karri floor. The corridor is floored with brush box. The western end houses the offices of the Chief and the Deputy Chief, the room of the former being panelled in polished jarrah with a parquetry floor of similar timber, while that of the latter has red tulip oak panelling and a myrtle floor. Adjoining these rooms is a small visitors room panelled in silky oak with a red tulip oak floor. The corridor at this end is floored in Sydney blue gum. The remainder of the first floor is occupied by offices and draughting and computing rooms.

At the eastern end of the second floor are the chemical laboratories on the north side, and the paint and glue and preservation laboratories

on the south side. These sections are served by a common storeroom and a balance and ovens room. A feature of the chemical laboratories is the arrangement of the general purposes benches along the outside wall, and narrow extraction benches with steam supply along the inside wall.

The remainder of the northern side is taken up by the photography and the dark room and the timber physics office, laboratories, and ovens and balance room. The Wood Structure Section is on the south side at this end of the building, and comprises a laboratory, office, and museum 30 feet x 20 feet. The first named two rooms are floored in narrow strip Tasmanian oak and the last named in red tulip oak, while the partition wall between the rooms displays the pleasing appearance to be obtained from knotty Pinus radiata. The corridor floors are mountain ash at the east end and Sydney blue gum parquetry opposite the stairs, while at the west end an interesting effect has been obtained by mixing indiscriminately Australian hardwood species varying widely in colour.

The roof is flat to provide space for exposure tests, and provision has been made for the installation of a lift when the fourth story is added.

Immediately at the rear of the main building, the Timber Mechanics Section is housed in a single story wooden structure 88 feet long by 34 feet wide. This is sheathed on the outside with hardwood weatherboards and on the inside with Pinus radiata lining, both timbers being finished in natural colours. At one end are offices and storeroom; at the other are the small universal testing machines (30,000 lb. Denison and 20,000 lb. Southwark Emery), and the Denison toughness machine. In the centre there is in the roof, a tower like projection the full width of the building, to give head-room for the 600,000 lb. Southwark Emery testing machine. Most of the equipment of this machine is housed in a pit 10 feet deep below the floor, but projecting above the floor level are the control cabinet and the loading crosshead, screws, and guides, the top of the last-named being about 30 feet above floor level. To give an unobstructed area around this equipment, the conventional type of roof truss with a tie beam has been replaced in the centre spans by special tieless trusses built up with timber connectors. Between the large testing machine and the offices and store, the box-testing drum and the bending machine with its steaming chamber are located. The equipment of this laboratory with such a fine range of mechanical testing equipment has been made possible by the generous gift of £5,000 by Mr. Russell Grimwade.

An existing single-storied building on the eastern side of the site has been renovated and converted into laboratories and now houses the hot water heating system boiler, a low pressure steam boiler—both automatically oil fired—a drying room, a seasoning laboratory and three offices, and a preservation and glue laboratory. In the seasoning room, the five experimental kilns have been re-installed, and advantage has been taken of the shift to overhaul and modify these to give improved performance. Two steaming boxes, a band saw, and drying ovens and balances complete the equipment.

The pressure preservation cylinder and its auxiliary equipment has been rearranged at the rear end of this building. With more space available, it has been possible to improve the layout and the controls are now centralised. A glue mixer, a glue spreader, one large and a

number of small hydraulic presses with their hydraulic pump system are located in this laboratory for investigations on the behaviour of glues and the gluing of timber, veneers, etc. Grinding plant for preparing wood samples for chemical analysis is also located here.

On the western boundary an existing building has also been renovated to hold the engineering and woodworking services of the Division. Lathes for precision and general work, drilling machines, a milling machine, blacksmithing and oxywelding plant are provided for the manufacture and repair of metal equipment, while band and circular saws, jointers, and a thicknesser will take care of the preparation of timber specimens.

The back of the block is reserved for a saw mill, and the first unit of this will consist of a power-feed circular breast-bench and a docking saw. At a later date a head saw for breaking down logs will be added.

The change from the old coach-houses, stables, and sheds at East Melbourne to these premises provides a great contrast, and there can be no doubt that the efficiency of the work of the Division will benefit enormously.

The Control of Silverfish.

The common name of "silverfish" is applied to a group of silvery-grey, wingless insects which cause serious damage in shops, houses, offices, and libraries. In Australia, *Ctenolepisma longicaudata* Esch. is the species responsible for most of this damage.

It is generally recommended that silverfish can be controlled by using, as baits, cards covered with a mixture of arsenic and flour or starch paste, but recent extensive tests carried out in the Division of Economic Entomology at Canberra have shown that *C. longicaudata* will not attack such baits. Further experiments showed that arsenic actually repels them. This bait was originally recommended against the silverfish *Lepisma saccharina L.,* common in Europe and North America.

This year tests with baits were carried out using 25 different toxic substances, and of these, barium fluosilicate and zinc borate gave the most satisfactory results. These substances, unlike most of the others tested, were not repellent. The most attractive paste was made of flour, rather than starch, and sweetened with sugar—too much sugar actually makes the paste less attractive.

The baits can be prepared as follows:—The sweetened paste is made of 1 oz. flour, 1½ oz. sugar and 10 fluid oz. water, and to the warm paste the poison is added—barium fluosilicate ¼ oz. or zinc borate ⅛ oz. The mixture should be spread on pieces of white cardboard (3 inches x 2 inches is a convenient size) and allowed to dry. From ten to twenty cards may be set out in each infested room in places where silverfish are commonly seen. They should be left undisturbed as long as possible.

If a building is heavily infested, it is recommended that before distributing bait cards, each room should be sprayed thoroughly with a commercial pyrethrum kerosene preparation (any well known fly spray can be used) once a week for at least two weeks. The spray should be forced into all cracks and crevices and is best applied at night when silverfish are most active.

This treatment, if carried out thoroughly, will reduce the infestation considerably but cannot completely exterminate the pest. The purpose of the poison baits is to destroy the remaining silverfish and to prevent renewed infestation.

The Oriental Peach Moth in the Goulburn Valley (Vic.)

The Oriental peach moth has caused serious losses to the canned peach industry of the Goulburn Valley during the past few years. In the season 1933-34, a serious outbreak occurred. In the subsequent season, the loss was 20 to 28 per cent., but in the 1935-36 season the loss was estimated at 50 to 52 per cent., which was almost as serious as the outbreak of 1933-34. It would thus seem that heavy infestation has become normal and that outbreaks are unlikely to be merely sporadic. The losses are in fact so great that they threaten the existence of the canned peach industry.

Although peaches are the chief fruits attacked by the moth, almond fruit and twigs, apricot fruit, plum twigs, pears, and quinces may also be attacked. The larvae of the first and second broods cause extensive damage to young succulent tips, a single larva attacking three tips in the course of its feeding period. The larvae of the third and fourth broods attack the fruit. Injury to quinces and late season's growth on young peaches and almonds is caused by the fifth brood larvae.

In 1934, the Commonwealth Bank and the Canned Fruits Control Board provided funds for an investigation of this pest, which has since been carried out by an officer of the Council for Scientific and Industrial Research in association with the Victorian Department of Agriculture (see this *Journal* (8) : 171, 1935).

The ideal method of control of any pest is by means of a natural enemy. In certain parts of the United States of America, the Oriental peach moth is effectively controlled by parasites, and, through the generosity of the United States Department of Agriculture, two kinds of parasites, believed to be the most efficient, were first introduced into Australia towards the end of the year 1935. They were bred in quarantine insectaries at Canberra and liberated in the Goulburn Valley.

The parasites in question are known as *Macrocentrus ancylivorus* and *Glypta rufiscutellaris*. Both lay their eggs on the larvae of the peach moth which are ultimately destroyed by the parasites. It must be pointed out, however, that even in some parts of the United States of America these parasites have failed to control the Oriental peach moth, and there is reason to suspect that the conditions in the Goulburn Valley may not be suitable for them. For instance, *Macrocentrus ancylivorus* is very sensitive to low humidities and high temperatures, while *Glypta rufiscutellaris* requires an alternative host, which lives in a weed, to carry it over part of its life cycle.

Another consignment of the two parasites will reach Australia from America very shortly, and further endeavours will be made to breed and liberate them in large numbers throughout the affected district during the present season. The parasites will be given the best possible chance to establish themselves, but beyond this nothing can be done to assist them to control the Oriental peach moth, and the fact must be

faced that they may not be able to control the moth. Therefore, concurrently with work on the parasites, investigations are being carried out to determine if there is any other possible method of controlling the pest.

Experiments have been conducted with a large number of different insecticides to find a substance which will destroy both the eggs and the young caterpillars. These two stages are the only ones which can be reached by spray materials. More detailed experiments will be carried out during the coming season with certain of the insecticides which have shown promise. Much work along similar lines has been carried out overseas, particularly in the United States of America, but so far no satisfactory spray schedule has been evolved. The special difficulty is due to the habits of the larvae and the vigorous growth of the peach. New tissues are rapidly produced throughout the season, so that cover sprays cannot long remain effective. The rapid production of new growth and the variation in the time of brood emergences in different orchards throughout the district make it necessary to time very accurately the application of sprays, so that each spray is applied at a time when the vulnerable stages of the insect are present. However, the work in the Goulburn Valley has shown sufficient promise to warrant continuance of the study of insecticides.

This year, the Commonwealth Bank and the Canned Fruits Control Board have provided between them a total sum of £3,500 in order that an intensive programme of work may be carried out during the next two seasons. More equipment, including a new insectary specially constructed at Mooroopna for parasitic breeding, has been obtained, and additional staff will be employed. Thus, fully equipped, a team of investigators is making every effort to obtain as quickly as possible a satisfactory and economic method of control of the pest.

A Note on the Use of Caustic Soda as a Dispersing Agent in the Mechanical Analysis of Soils.

(*Contributed by Allan Walkley, B.Sc., B.A., Ph.D.**)

The adoption of caustic soda as a dispersing agent was suggested by Commission I. of the International Society of Soil Science at Versailles in 1934. Ammonia and other dispersants were also recommended provided it could be shown that they gave substantially the same results as did caustic soda[1].

The majority of mechanical analyses at the Waite Institute have been carried out in conjunction with soil survey work where only a few major soil groups have been involved. Tests on members of these groups have shown that caustic soda possessed no advantages over ammonia from the point of view of high dispersion, and, since the ammonia has certain practical advantages, chief of which is the fact that any excess is removed by evaporation, it has been used almost exclusively. Recently, however, some soils from the Murrumbidgee Irrigation Area and belonging to the grey and brown soil group, were

* Of the Council's Division of Soils which has its headquarters at the Waite Agricultural Research Institute of the University of Adelaide.

1 Trans. 3rd Internat. Congress of Soil Science 1935, Vol. III., p. 252.

found to give much higher clay figures when caustic soda was used as dispersant. Analyses carried out by N. H. Parbery, G. D. Hubble, and C. H. Williams indicated that the clay contents by the caustic soda method on eighteen soils exceeded those by the ammonia method in all cases. In fourteen of these soils the amount did not exceed 4 per cent., but for the remaining four soils differences amounted to as much as 15 per cent. (Differences of a similar magnitude are quoted by Robinson for two soils from the Sudan[2].)

The results are given below:—

Soil No.	Percentage Clay.		Difference.
	By NH_4OH.	By NaOH.	
10	51	58	7
21	46	61	15
59	50	57	7
69	36	51	15

It is of some interest that the texture of many of these soils as determined in the field appears to be very much lower than the clay contents would indicate. Judging by the standards adopted for other irrigation areas, even the clay content by the ammonia method is much in excess of what would be expected from field description. It seems probable that the clay present in these soils is of a different nature from that previously encountered in the survey work of the Soils Division.

In the cases just discussed, the low clay values by the ammonia method were more or less counterbalanced by high silt values, so that the sums of the various fractions approximated well to 100 per cent. For two Mallee subsoil samples representing cemented hardpans from Lake View, New South Wales, however, summations of about 85 per cent. were obtained when using the ammonia method, the clay actually coming down with the fine sand fraction. Caustic soda, on the other hand, gave satisfactory results.

Although determinations with caustic soda on a number of samples from previous surveys have not disclosed any further cases where differences in the two methods occur, yet it is suggested that for future determinations on Australian soils caustic soda be used as the dispersant.

Bulletin of the Imperial Institute.

The scope of the Bulletin of the Imperial Institute has recently been extended. In consequence, the publication will be of considerable interest to quite a number of people who do not regularly see it. As from the beginning of its current volume (No. 34) covering the year 1936, articles, notes, and bibliographies on minerals and mineral products will be included. The Bulletin will still continue to contain its usual articles and other information on plant and animal products.

[2] Physique du Sol. International Society of Soil Science 1934, p. 15.

Prior to the year 1926, the Bulletin contained some information concerning minerals, but in that year, after the amalgamation of the Imperial Mineral Resources Bureau with the Imperial Institute, the mineral activities of the latter were concentrated on answering inquiries and in writing brochures; mineral contributions to the Bulletin declined in consequence. As indicated above, however, this position will now be entirely changed.

A further innovation has been the elimination of all paid advertisements from the Bulletin, and instead the exchange of free advertising matter with associations and societies which recognize and practise the study of economic, cultural, or educational interests of the Empire.

With the change in the current volume, the opportunity has also been taken to reduce the price from 15s. per annum to 10s. per annum, post free. The Bulletin is a quarterly publication and each issue contains some 150 pages of subject matter.

The Bulletin is a means whereby the Institute carries out one of its functions which broadly are to promote the commercial, industrial, and educational interests of the British Empire, to collect and disseminate information concerning raw materials or semi-manufactured products and the marketing of such, and to conduct in its laboratories preliminary investigations of raw materials, and, when it may be deemed advisable, to arrange for more detailed investigation by appropriate scientific or technical institutions. The Institute was founded as the Empire Memorial of the Jubilee of Queen Victoria.

The first two numbers of the current volume of the Bulletin have now reached Australia. They contain articles concerning hides from curing experiments, clarified butter (ghee), recent developments in gold mining in Tanganyika, chaulmoogra oils, cacao fermentation, tung oil in Kenya, metallic and inorganic weedkillers, &c., and numerous notes on such matters as low temperature carbonization of torbanite, the metal industries of Italy, aluminium powder in paints, talc, the coloration of glass, corundum, lead titanate as a pigment, &c.

The Institute hopes that its recent re-organization of its Bulletin will induce a number of libraries, industrialists, and others who have the commercial development of the Empire at heart to contribute. Inquiries should be addressed to the Director, Imperial Institute, South Kensington, London, S.W.7.

Recent Publications of the Council.

Since the last issue of this *Journal*, the following publications of the Council have been issued:—

Pamphlet No. 65.—" A Survey of the Sheep and Wool Industry in North-Eastern Asia." With special reference to Manchukuo, Korea, and Japan, by I. Clunies Ross, D.V.Sc.

Towards the end of the year 1935 the Council was asked by various authorities to allow the Officer-in-Charge of its F. D. McMaster Animal Health Laboratory (Dr. I. Clunies Ross) to visit Eastern Asia. It was considered that such a visit would be useful as it would enable Dr. Ross to look into—(*a*) the scientific aspects of the sheep breeding work

which Japanese authorities have recently commenced in Manchukuo, Korea, and Japan; and (*b*) the practical possibilities of the movement for increasing the sheep population of these countries. The visit was made early in the year 1936, and the Pamphlet consists of the report Dr. Ross submitted on his return. In brief, he reaches the conclusion that owing to the severe climatic conditions that occur, there is little, if any, reason to believe that the present sheep population, which incidentally is comparatively small, can be appreciably increased. The author also discusses the growing demand for wool that exists in Japan and China.

Pamphlet No. 66.—" The Sheep Blowfly Problem in Australia. Results of Some Recent Investigations," by I. M. Mackerras, M.B., Ch.M., B.Sc.

The need for a paper giving an outline of recent work carried out by the Council's blowfly research team, and placing the parts of that work in proper perspective, has been met in this publication. The latter has been prepared with a view to giving readers a general idea of investigations at present in progress, together with a clear understanding of the problem as it occurs in Australia. Blowfly strike is treated as a disease of sheep, and the cause of the disease, its pathology, and its chief complications are described. A brief account is also given of present-day methods of treatment and prevention.

Forthcoming Publications of the Council.

At the present time, the following future publications of the Council are in the press:—

Bulletin No. 102.—" Studies of Selected Pasture Grasses. The Measurements of the Xerophytism of any Species," by T. B. Paltridge, B.Sc., and H. K. C. Mair, B.Sc.

Bulletin No. .—" *Wojnowicia graminis* (McAlp), Sacc, and D. Sacc. In Relation to Foot Rot of Wheat in Australia." By W. V. Ludbrook, B.Agr.Sc., Ph.D.

Pamphlet No. .—" The Shrinkage of Australian Timbers "— Part I. A New Method of Determining Shrinkages and Shrinkage Figures for a Number of Australian Species. By W. L. Greenhill, M.E.